THE IRRIGATION WORKS
OF INDIA,

AND THEIR

FINANCIAL RESULTS.

BEING

A BRIEF HISTORY AND DESCRIPTION OF THE IRRIGATION WORKS OF INDIA,
AND OF THE PROFITS AND LOSSES WHICH THEY HAVE CAUSED
TO THE STATE.

BY

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LONDON:
[illegible]LLEN & CO., 13 WATERLOO PLACE.
PUBLISHERS TO THE INDIA OFFICE.

LONDON
PRINTED BY W. H. ALLEN AND CO., 13 WATERLOO PLACE

PREFACE.

The contents of the following pages have been compiled from the many sources of information, chiefly Government Reports and Parliamentary Papers, which are mentioned in the foot-notes. In some cases the descriptions have been taken verbatim from the authorities named. The author is indebted to the courtesy of the officials at the India Office for access to many of the records quoted.

There exists at present no book which gives any comprehensive account of the Irrigation Works of India. The author often found, in India, the greatest difficulty in obtaining any information concerning any other irrigation works than those on which he was employed; and he has often heard the wildest statements made, as to the profits or losses accruing to the Government on irrigation works, by men whose opinion carried some weight. He hopes, then, that to his brother officers of the Irrigation Department, and, perhaps, to others, this brief account of the Irrigation Works of India will be acceptable. That it is imperfect, and, perhaps, not perfectly accurate in some details, he is well aware; but he believes that he has consulted the best sources of information available, and that the description of the works is as accurate as it can be made without local investigations.

R. B. B.

London,
August 24th, 1880.

CONTENTS.

CHAPTER I.

INTRODUCTION.

Commencement of Public Works—Guaranteed Companies—Irrigation Works constructed on Loan—Schemes of 1868 to 1871—Expenditure on Irrigation Works and Railways—Classification of Works—Rainfall . . . . p. 1

CHAPTER II.

IRRIGATION WORKS OF THE MADRAS PRESIDENCY.

The Godavari—Kistnah—Pennair—Cauvery—Chembrambaukum Tank—Palar Project—Vellore Delta Works—Statement of Areas irrigated—Madras Irrigation Company . . p. 11

CHAPTER III.

THE IRRIGATION WORKS OF BOMBAY.

Classification—Mutha Canals—Jamda Canals—Krishna Canals—Lakh Canals—Palkher Canal—Ekruk Tank—Hathmati Canal—Bhatodi Tank—Maini Tank . . . . p. 34

CHAPTER IV.

THE IRRIGATION WORKS OF SIND.

Indus Delta—Inundation Canals—Sind—Ghar—Western Nara—Begari—Eastern Nara—Fuleli—Sukhur and Shahadadpur p. 52

CHAPTER V.

BENGAL IRRIGATION WORKS.

Rainfall—Prejudice against Irrigation—Orissa Canals—Midnapore Canals—Tidal Canal—Sone Canals—Sarun and Hooghly Schemes—Proposed Extensions . . . . . . p. 63

CHAPTER VI.

THE IRRIGATION WORKS OF THE NORTH-WEST PROVINCES.

The Jumna and Ganges—Rainfall—Eastern Jumna Canal—Ganges Canal—Agra Canal—Dun Canal—Bijnor Canals—Rohilkhund Canals—Bundelkhund Canals—Lower Ganges Canal—Eastern Ganges Canal . . . . p. 88

CHAPTER VII.

PUNJAB IRRIGATION WORKS.

The Punjab Plains—Area protected—Western Jumna Canal—Bari Doab Canal—Lower Sutlej and Chenab Inundation Canals—Upper Sutlej and Chenab Inundation Canals—Indus and Chenab Inundation Canals—Delhi and Goorgaon Canals—Shahpur Canal—Sirhind Canal—Swat River Canal . p. 129

CHAPTER VIII.

FINANCIAL RESULTS.

Financial Results best Test of Utility—Difficulties of showing Exact Results—Direct and Indirect Revenue—Forms of Account—General Dickens's Statements—Results of 1876–77—Profit due to seven Works—Future Accounts—Time before Irrigation Works will pay—Results of 1877–78 . . p. 172

THE

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CHAPTER I.

INTRODUCTION.

Commencement of Public Works.—Guaranteed Companies.—Irrigation Works constructed on Loan.—Schemes of 1868 to 1871.—Expenditure on Irrigation Works and Railways.—Classification of Works.—Rainfall.

PREVIOUS to 1854 all public works, except railways, which were executed in India were carried on by the Engineer Department of the Army under the superintendence of a military board. The expenditure incurred was treated as "ordinary," and was charged against the revenue of the year; no capital or revenue accounts of the works were kept. For this reason it is difficult, almost impossible, in the case of the older works, to find out their actual financial position. It was under this system that a portion of the Ganges canal (commenced 1847), the West Jumna canal (1817), and the works of the Cauvery (1834), the

Godaveri (1844), and Kistna (1852) deltas were commenced. The system of charging the cost of large "reproductive" works against yearly revenue was soon recognised as a false one, and it was decided that only such works were to be charged against yearly revenue as came under the following definition*:—

> Those relating to the maintenance and erection of civil and military buildings, the repair and construction of roads, and the other multifarious works necessary for the smooth and effective working of the administration of a great empire.

While works which were of public utility, such as railways, canals, and harbours, and which were calculated to increase the wealth and promote the prosperity of the country, were to be constructed from borrowed funds and treated as commercial undertakings. Of these latter works proper capital and revenue accounts were to be kept.

In 1846 the Government had commenced the construction of railways under what is known as the guarantee system. Under this system the Government guaranteed 5 per cent. on the capital expenditure of those companies which undertook the construction of railways. The Government retained considerable command over the operations of the companies; they controlled the routes, and no expenditure was undertaken until sanctioned by the Government officers. The companies raised the money required for the works; the interest on it was payable as soon as the money was raised, although it might not have been spent. This policy of guaranteed companies was eventually found to be anything but an economical one, and was abandoned in 1867, but it was in full play in 1858, when great pressure* was brought upon the Government of India to promote irrigation by the same indirect agency as that by which they were then extending railway communication, the Madras Irrigation Company was formed, with a Government guarantee of 5 per cent. upon a capital of one million pounds; and a few years after another private company (the East India Irrigation Company) undertook, without a guarantee, the construction of a system of irrigation canals in Orissa. Both these experiments have proved costly failures to the State. But about 1863 the status of guaranteed companies was so far assured, and the East India Irrigation Company seemed to consider themselves so certain of success, that a proposal was actually made† by the secretary of that company in 1863 or 1864 to purchase the works of the Ganges canal from the Government for one and a half millions sterling. It was proposed that all returns up to 25 per cent. on the capital were to be retained by the company, any surplus beyond that was to be divided between the company and the Government.

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* **Report of Select Committee on India Public Works, 1879, p. iii.**

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* Report of Select Committee on India Public Works, 1879, p. vi.

† Copies of Despatches ordered to be printed by the House of Commons, 6th March 1867.

The arrangement between the Secretary of State and the Orissa or East India Irrigation Company soon became so involved, that it was considered advisable to terminate the contract by the purchase of the works of the company at a price much above their market value. This sale was effected at a time when the company was practically bankrupt. The Madras Irrigation Company, since its formation, has succeeded for one year only in meeting its working expenses. These two companies were the only ones connected with irrigation works in India. The Madras Company still continues to carry on its works under the Government guarantee. The East India Irrigation Company was purchased by the Government in 1867, at which date the Government had decided that both railway and irrigation works should be constructed directly by their own agency, which they considered to be more economical and more easily controlled than the guarantee system.

Shortly before this decision was reached, the Government of India, in a despatch dated the 15th of March 1866 to the Secretary of State, pointed out that what the Government desired was a permanent and persistent effort to carry out gradually a large extension of irrigation works. They desired to raise loans to be devoted exclusively to this purpose, for they feared that unless the principle of steady progress was definitely accepted, it would never be found financially convenient* to carry on works from beginning to end with proper vigour. The effect of depending from time to time upon the fluctuations of the money market would be the same as that of depending on occasional years of surplus revenue. In times of pressure the progress of works would be starved, and in times of financial prosperity attempts would be made to push forward without experienced establishments or matured arrangements.

In reply to this despatch the Secretary of State (No. 200, dated 23rd August 1866) expressed his willingness to sanction the raising of any loans necessary to construct reproductive irrigation works, the estimates of which had been thoroughly matured, and of which reasonable expectation was maintained that they would prove remunerative. In consequence of this, great activity prevailed in the Irrigation Department during 1867–68–69. Many schemes were proposed and surveyed, and the staff of engineers was largely increased. In 1869 the Government of India† reported to the Secretary of State that they had received such information as enabled them to form a good approximate estimate of the probable outlay required during the next ten years. Schemes estimated to cost thirty millions sterling were roughed out, and the Government of India proposed to spend one million six hundred and fifty thousand pounds in 1869–70, two and a half millions in 1870–71, three millions in 1871–72, and after that four millions a year on irrigation works.

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* Copy of Despatches ordered to be printed by the House of Commons, 6th March 1866.

† Copies of Correspondence ordered by the House of Commons to be printed 27th July 1870.

The schemes proposed included* extensions and improvements of the Great Madras Works, new works and extensions in Bombay, large perennial canals in Sind to replace the many inundation canals there, extensions and improvements on the west bank of the Indus, modifications and extensions of the Baree Doab canal, the Sirhind canal, provision for the irrigation of the whole of the eastern part of the Punjab as far as the Ravee, a new canal from the Jumna a little below Delhi, a great system of canals to irrigate the province of Oude from the river Sardah, the Sone canals, the Midnapore canals, the Orissa canals, a project for the irrigation of the district bordering on the Gunduck river in Bengal, a canal to leave the Ganges near Rajmahal chiefly for purposes of navigation, and many other schemes. The magnitude of these projects, of which some have since been carried out and some are in progress, may be imagined from the fact that the area they were intended to protect was about equal to half of France and to the whole of Italy.

The sums actually expended are given in the following statement† which shows the amounts expended on productive public works in each year from 1867–68 to 1877–78 inclusive, the amounts expended on irrigation works and State railways are separately given.

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* Despatch No. 21 of 8th February 1869, ordered by the House of Commons to be printed 27th July 1870.

† Appendix III., V., and VII., Report of Select Committee on East Indian Public Works, 1879.

Year.	Irrigation Works.	State Railways.	Total.
	£	£	£
1867–68	219,255	594	219,849
1868–69	468,849	552,398	1,021,247
1869–70	2,007,361	190,870	2,198,231
1870–71	718,438	449,372	1,167,810
1871–72	983,854	644,620	1,628,474
1872–73	770,920	1,413,649	2,184,569
1873–74	1,198,682	2,354,625	3,553,307
1874–75	1,235,391	3,014,180	4,249,571
1875–76	1,105,445	3,165,184	4,270,629
1876–77	943,423	2,865,861	3,809,284
1877–78	918,317	3,984,968	4,903,285
Total £	10,569,935	18,636,321	29,206,256

The expenditure on famine relief during these years amounted to no less than fourteen and a half millions sterling.

The depressed state of the Indian finances during late years has greatly reduced the power of the Government to prosecute their plans, and many doubts have been thrown on the wisdom of such great extension of irrigation as was contemplated in 1869. The returns have not been nearly as large as was predicted. The Secretary of State has now directed that only two and a half millions a year are to be expended on reproductive public works, including railways, and this decision has met with the approval of the Select Committee of the House of Commons in their Report issued in 1879.

In the following brief account of the irrigation works of India, they are divided into different groups corresponding with the provinces in which they are situated, viz.:—

(1.) The Madras Irrigation Works.
(2.) Irrigation Works of Bombay.
(3.) The Irrigation Works of Sind.
(4.) The Bengal Irrigation Works.
(5.) Irrigation Works in the North-West Provinces.
(6.) Punjab Irrigation Works.

These comprise all the important works of India; there are others of much less magnitude, chiefly tank works in Mysore, Rajpootana, and British Burmah, but as these are not included in the works considered by the Select Committee on East India Public Works 1878–79, and as the available sources of information give little if any account of them, they are omitted. The works may be divided into five great classes:—

1st. Perennial Canals. Works drawing their supply from rivers of which the discharge is, at all times of the year, sufficient, without storage, to supply the canals.

2nd. Intermittent Canals. Works which draw their supply from rivers having an uncertain and very variable discharge, which is stored and rendered constantly available for the canals by means of reservoirs formed in the basins of the rivers themselves.

3rd. Chronic Canals. Works fed from rivers having a supply available during the rainy season only.

4th. Inundation Canals. Works drawing their supply from rivers having a constant discharge of more or less magnitude, but which are so constructed that the water of the rivers only enters the canals at those times when the rivers are in flood.

5th. Tanks. Works which impound a supply either from rivers with small catchment areas, or collect a supply by means of long embankments thrown across valleys, or by means of short embankments across gorges.

Works of the last two classes were largely constructed by the natives of India before the English Government obtained possession of the country; they are to be found, on all scales, in almost all parts of India; from the Great Chembrambaukum tank—nine square miles in area—in Madras, to the petty "ahrahks" or embanked ponds of Behar; and from the great Inundation canals—two hundred and three hundred feet wide—in the Punjab and Sind, to the petty "pynes" which lead off from many small rivers and streams in north-western Bengal and elsewhere. All the Perennial canals are, with one or two exceptions, works constructed by the British Government. The statement attached to each chapter shows to which of the above five classes each canal belongs.

The statement on the next page shows the rainfall of the different districts of India as divided by the Meteorological Department of Calcutta into rainfall tracts.

The tracts numbered XVII. and XVIII. correspond as near as may be with the districts commanded by the Madras Irrigation Works, and those numbered X., XI., VII., III., and II. with the works of the other provinces in the order 2, 3, 4, 5, and 6 as they are mentioned above. The rainfall of the country actually commanded by any canal is given, if it is obtainable, in the statements appended to the chapter on each province.

STATEMENT of RAINFALL in different Tracts of India, from information given by the Meteorological Department, Calcutta.*

	Tracts.		Rainfall in Inches.
I.	Western Himalaya		65
II.	Punjab Plains		22
III.	Upper Gangetic Plains, North-West Provinces		38
IV.	Eastern Himalaya		144
V.	Lower Gangetic Plains		68
VI.	Assam and E. Bengal		96
VII.	Western Bengal		56
VIII.	Central India and Nerbudda		44
IX.	Rajputana and Gujerat		32
X.	Sind and Kutch		9
XI.	Khandeish and Berar		29
XII.	Central Provinces (South)		49
XIII.	North Deccan Plateau		28
XIV.	Hyderabad and S. Deccan		25
XV.	Concan and Ghats		145
XVI.	Malabar and Ghats		112
XVII.	Carnatic	Madras	34
XVIII.	Northern Circars		36
XIX.	Arakan		193
XX.	Pegu		76
XXI.	Tenasserim		173
XXII.	Bay Islands		108

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* Published in the Report of the Select Committee on Indian Public Works, 1879.

CHAPTER II.

IRRIGATION WORKS OF THE MADRAS PRESIDENCY.

The Godaveri.—Kistnah. — Pennair.—Cauvery. — Chembrambaukum Tank.—Palar Project.—Vellore Delta Works.—Statement of Areas irrigated.—Madras Irrigation Company.

WITH the exception of the Western Jumna canal in the Punjab, the oldest of the irrigation works undertaken by the British Government in India are those of the Madras Presidency. The statement on p. 12 shows the principal works and gives some statistics concerning them.

Godavari Delta System.

The Godavari anicut or weir was commenced in 1844–45 for the supply of the canals of the delta at the head of which it stands. The river drains an area of about 115,570 square miles; the crest of the

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* This historical notice is taken from the "Annual Progress Report of the Irrigation Branch in the Madras Presidency for 1877-78."

Works.	Source of Supply	Completed up to 1878.			Approximate Annual Rainfall.	Area actually irrigated during last year of which returns are obtainable.	Approximate cost of Works without interest.	Approximate area commanded by the canals.	Population per square mile in 1872.	Class.
		Miles of Main and Branch Canal.	Miles of Distributaries.	Miles of these which are navigable.						
MADRAS.						Acres.	£	Acres.		
Godaveri Canals . .	Godaveri	442	Not given	442	About 34 to 36 inches.	541,892	787,778	1,000,000	256	Perennial
Kistna Canals. . .	Kistna	267	Not given	267		246,090	484,054	470,000	181	Perennial
Pennair Canals . .	Pennair					54,102	134,020	77,000	163	Perennial
Vellore Delta Works .	Vellar						25,300			Perennial
Cauvery Canals . .	Cauvery					796,968	133,964	835,000	540	Perennial
Streevigantam Project .	Taunapurni					30,019	106,060	32,000		
Madras Waterworks with combined Irrigation Project.							125,236		341	
Chembrumbaukum Tank	Reservoir						48,256	5,729	341	Tank
Palar Project . . .	Palar					37,672	108,371		282	
Madras Irrigation Company.	Toombudra					82,477	1,708,211	200,000	156	Perennial
							3,661,250	2,619,729		

anicut is at 38 feet above mean sea level, and it is situated at about 33 miles from the coast. The length of the crest of the weir, on the line of which the river is divided into four branches, is 3,938 yards. The greatest depth of water which has passed over the weir is 15·25 feet. A short distance below the weir, the river forms two main branches with a central delta between them.

There are three main canals, that of the eastern delta has a bottom width of 184½ feet, and, when carrying a full supply, the water is 8·21 feet deep; that of the central delta will be 114 feet wide at bottom, with a depth of 7 feet of water; that of the western delta varies considerably in width, but where the water is carried in a single channel the bottom width is about 225 feet, and the full depth of water 10 feet. All the principal canals of the delta are navigable. The length of canals now available, or shortly to be ready, for navigation is 518 miles, and many of them have, during the last five years, been much improved by the construction of new locks and the reduction of the current. The total area of the delta is about 2,023 square miles. Extensive works for the improvement of navigation and drainage have been undertaken since 1870 in the eastern and western deltas. This system commands about 1,000,000 acres.

The following statement shows the length of navigable canals open and the progress made in 1877–78.

Name of Canal.	Proposed total Length.		Completed and Navigable.			
			Up to 1876–77 inclusive.		Up to 1877–78 inclusive.	
	Ms.	Chs.	Ms.	Chs.	Ms.	Chs.
Eastern Delta:						
Main Canal . . .	4	12	4	12	4	12
Samulcottah Canal . .	34	28	34	28	34	28
Cocanada Canal . .	27	48	27	48	27	48
Bank Canal . . .	38	40	29	50	29	50
Coringa Canal . .	24	37	24	37	24	37
Injeram Canal . .	11	9	11	9	11	9
Mundapetta Canal . .	13	35	13	35	13	35
Total . .	153	49	144	59	144	59
Central Delta:						
Main Canal . . .	8	0	8	0	8	0
Gunnaram Canal . .	44	0	28	0	28	0
Bank Canal . . .	41	0	35	0	35	0
Amalapur Canal . .	32	0	26	0	26	0
Bendarnurbunka Canal .	14	0	2	0	2	0
Bellakurru Canal . .	4	0	4	0	4	0
Vilsa Main Canal . .	7	0	—		—	
Kadally Canal . . .	7	0	—		—	
Total . .	157	0	103	0	103	0
Western Delta:						
Main Canal . . .	6	11	6	11	6	11
Kakarapurru Canal . .	10	15	9	4	9	4
Naraspur Canal . .	29	68	29	68	29	68
Bank Canal . . .	25	56	22	38	25	50
Mukkamala Canal . .	2	32	2	32	2	32
Gostanaddi & Velpur Canal	28	35	28	35	28	35
Ellore Canal . . .	40	27	28	40	28	40
Junction Canal . .	3	43	3	43	3	43
Venkkiah & Weyeru Canal	29	74	29	74	29	74
Undi Canal . . .	15	60	15	60	15	60
Attili Canal . . .	15	60	15	60	15	60
Total . .	208	1	191	65	194	77
Grand total . .	518	50	439	44	442	56

Kistna Delta System.

The Kistna anicut or weir was commenced in 1852. The site chosen is at a point where the river is much narrower than its normal width, its channel being there confined by rocky hills on either bank. The length of the crest of this weir is 1,280 yards. In 1874 the river rose to 19·42 feet above the weir-crest, and this was the highest fresh which has occurred since the anicut was built. The drainage-basin of the river has an area of about 110,000 square miles. The river divides the delta into two parts. The eastern delta main canal will, when completed, have a bottom width of 200 feet, and the depth of water be 8¼ feet. The main canal of the western delta will have a bottom width of 230 feet, and a depth of water of 8 feet.

The principal canals are navigable, and their length so available is at present about 267 miles. Some addition will hereafter be made to the extent of navigation by the extension or improvement of the canals. The area of the two parts of the delta is together 2,110 square miles; the ultimate area of irrigation is estimated at 470,000 acres.

The subjoined statement shows the length of navigable canals open, and the progress during the year 1877–78.

Name of Canal.	Proposed total Length.		Navigable.			
			Up to 1876-77 inclusive.		Up to 1877-78 inclusive.	
Eastern Delta:	Ms.	Chs.	Ms.	Chs.	Ms.	Chs.
Main Canal	0	45	0	45	0	45
Ellore Canal	40	0	40	0	40	0
Budameru Canal	37	0	20	0	20	0
Masulipatam Canal	49	13	49	13	49	13
Palleru Canal	26	62	17	62	17	62
Namurru Junction Canal	0	40	0	40	0	40
Buntumilly Canal	14	20	14	20	14	20
Polraykodu Canal	16	51	16	51	16	51
Total	175	71	158	71	158	71
Western Delta:						
Main Canal	13	0	13	0	13	0
Nizampatam	27	78	27	78	27	78
Bank Canal	45	60	21	0	21	0
Commanoor Canal	50	0	46	30	46	30
Total	136	58	108	28	108	28
Grand total	312	49	267	19	267	19

Pennair Anicut System.

The Pennair delta embraces a comparatively small area. On the north side of the river there are from 200 to 220 square miles of country, in which there are numerous tanks, which receive a more or less reliable supply of water; it has been proposed to improve radically the arrangements, but hitherto the irrigation was much in the state in which it was found when the district came into British possession. On the south side the area is 150 square miles, and has been provided with a fairly complete system of irrigation. The anicut or weir across the river was commenced in 1855, and was, until the year 1875, 527 yards in length, or about one-third of the normal width of the river. It has been lengthened to 677 yards to lessen its liability to damage. In the flood of 1874, 18·37 feet of water passed over the crest, and much of the country on both sides of the river was inundated. The area of the basin drained by the river is about 20,000 square miles. The ultimate area of irrigation is estimated at 77,000 acres.

Cauvery Delta System.

The Cauvery delta has the largest area of irrigation in Madras. About ten miles west of Trichinopoly the Agunda-Cauvery divides, at the head of the island of Srirangam, into two branches, the Coleroon and the Cauvery. Across the Coleroon a weir called the Upper anicut was constructed about the year 1834, and was one of the earliest of the great works planned by Sir Arthur Cotton. Its effects on the delta have been very great, and the benefits conferred on the Government and on the people of the Tanjore district have more than fulfilled the anticipations of the projector by securing a reliable supply of water, and obviating the necessity for collecting annually, or in some seasons several times during the year, many thousands of the cultivators to form temporary works for the diversion of water down the Cauvery. The head of this latter work is 1,950 feet wide, and the bed-level is regulated by a dam. After running for some 16 or 17 miles the Cauvery bifurcates into two main channels, the Cauvery and the Vennar, which irrigate nearly equal areas, and which give off numerous branches; at all the principal bifurcations regulating works have, during the last few years, been constructed. The Cauvery was formerly connected with the Coleroon at the east end of the island of Srirangam, some 20 miles from the Upper Coleroon anicut, and across this channel a work called the Grand anicut was built by the natives many years before the province of Tanjore was ceded to the British. This was the first step towards the improvement of the delta, and its effects must have been great.

In the northern deltas the whole of the distribution of water has been artificially carried out by canals; but in the Cauvery delta the principal distribution was effected naturally by the numerous branches thrown off by the Cauvery and Vennar; and from these branches innumerable small channels have been cut to convey water to the lands of the delta villages. The chief work to be done under the British Government, was firstly, to render the water-supply more reliable; this was secured by the Upper anicut: and secondly, to regulate the distribution by the principal rivers, towards which something was done formerly by the regulating works at the head of the Vennar, and much more during the last few years by the construction of regulators at the head of the principal branches. It is intended to bring the Cauvery under complete regulation, and to provide a new head for the Vennar at the Grand anicut, so that the delta may be entirely protected from excessive floods, and that water which cannot with safety be carried by the various rivers of the delta may be passed over the Grand anicut and discharged by the Coleroon river to the sea. Much useful work has been done in the delta towards regulating the widths of the rivers and improving the alignment. Formerly the river-beds varied greatly in width, and the result was that the deep channels changed from year to year, the tendency being to cut away the banks in some places, and to deposit the eroded material elsewhere. The parts of river-beds in excess of the width required have been planted up with a tall grass called nanal or durbah; this checks the current, causes a deposit of the silt held in suspension, and so gradually reclaims land in a very simple, effectual, and inexpensive manner.

The Cauvery rises in the western ghauts or mountains, and drains an area of about 28,000 square miles. The area of its delta is about 2,700 square miles. The system irrigates about 796,968 acres.

Chembrambaukam Tank System.

The Chembrambaukam tank is a large reservoir about 14 miles from Madras, which has been formed by enlarging an old native tank. Before its enlargement it held from 55·61 to 77·80 millions of cubic yards, and had an area of 4,648 acres or 7·26 square miles. Its present capacity is 102·91 millions of cubic yards and the waterspread is 5,729 acres or 8·95 square miles.

The old sources of supply have been utilised to a greater extent by enlarging the supply-channel and its head-sluice.

It is not yet known whether the extension of irrigation will realise the expectations entertained when the scheme was sanctioned. Originally it was intended to make the tank large enough to hold 196·87 millions of cubic yards, but a reconsideration of the scheme with reference to the water-supply available resulted in the alteration of the project to the dimensions above noted.

Vellore Delta Works.

The Pelandorai anicut gives its name to a system of irrigation in South Arcot. The anicut is built across the Vellar river, at the site which gives the work its name, and a supply-channel from the right bank, regulated by a head-sluice and connected with subsidiary channels, conveys water for the irrigation of fifty villages in the Chilambaram Taluk. The works were commenced in the year 1870 and are, with the exception of additional storage in tanks, practically completed to the extent of the original design.

Palar Anicut System.

The Palar anicut is thrown across the river of that name at the town of Vellore in the North Arcot district. It is 2,600 feet long and is the head of a system which irrigates about 37,672 acres. Channels provided with head-sluices take off on either bank above the anicut. The original work was constructed about the year 1855. It was damaged and partly carried away in 1874, and has since been restored.

Streevigantham Anicut System.

The Streevigantham anicut system is of considerable importance. The anicut crosses the Tamrapurni river in Tinnevelly about 16 miles from the sea, and is the lowest anicut on the river. It provides for the extension of irrigation on both sides of the river, the channels leading from which not only irrigate the land directly, but furnish supplies to existing tanks where the water is stored. The original estimate of the extent of land to be brought under cultivation was 32,000 acres. Little remains to finish off the project as sanctioned.

The eight works just described are those of which capital and revenue accounts are kept, as will be seen on reference to Chap. VIII.; they irrigate together about 1¾ millions of acres of crops, and bring in to the Government a net profit of about 17 per cent. on their capital cost. But it must not be supposed that these are the only works which are used to irrigate the fields in the Madras Presidency. The Madras works are divided by the local government into six classes:—

(1.) Irrigation works for which capital and revenue accounts are kept, and which are constructed from borrowed funds. This class contains only the eight works above described.

(2.) Works of which individual accounts are kept, but which are not constructed from borrowed funds. This class contains some forty-four small works, each costing on the average about one thousand four hundred pounds and irrigating about 4,000 acres.

(3.) Minor irrigation works supplied by rivers and streams.

(4.) Tanks in groups.

(5.) Isolated tanks.

(6.) Miscellaneous irrigation works, including spring channels, ponds, wells, and any other works from which revenue may be derived.

The eight works of Class 1 are those which are called "reproductive" works by the Government of India and are those of the greatest magnitude, but the statement * on p. 23 shows that, although these eight works bring in large profits to the State, the minor works are perhaps equally important to the people, since 3,476,000 acres are irrigated by them, or about twice the area irrigated by the eight "reproductive" systems.

Madras Irrigation Company's Canal.

The works of the Madras Irrigation Company in the districts of Ballary, Kurnool, and Cuddapah in Madras are the only works in India under the administration of a company having a capital guaranteed by Government. The company was incorporated by an Act of

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* Annual Progress Report of the Irrigation Branch of the Madras Presidency for 1877–78.

District.	Total Area and Revenue due to Irrigation.		Area and Revenue due to eight Systems.		Area and Revenue due to works for which continuous record is kept individually.		Area and Revenue due to the Works already grouped.										Area and Revenue due to Works not yet grouped.	
	Area.	Revenue.	Area.	Re-venue.	Area.	Re-venue.	A. Works supplied from Rivers and Streams.		B. Tanks in Groups.		C. Tanks isolated.		D. Miscellaneous Irrigation Works.		Total.		Area.	Re-venue.
							Area.	Re-venue.	Area.	Re-venue.	Area	Re-venue	Area.	Re-venue.	Area	Re-venue.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Acres	Rs.	Acres	Rs.	Acres	Rs.	Acres	Rs.	Acres	Rs.	Acs.	Rs.	Acres	Rs.	Acres	Rs.	Acres	Rs.
Ganjam -	297,641	5,78,131	—	—	—	—	—	—	—	—	—	—	—	—	—	—	297,641	5,78,131
Vizigapatam	166,676	2,99,088	—	—	8,207	42,714	—	—	—	—	—	—	—	—	—	—	158,469	2,56,374
Gadavari -	603,387	24,74,793	524,137	23,39,265	—	—	6,441	19,558	29,644	1,16,989	1,050	4,182	—	—	37,135	1,40,729	63,333	41,029
Kistna -	278,324	11,88,169	246,090	10,98,978	—	—	7,822	35,156	817	4,550	390	2,159	1,987	1,096	11,016	42,961		
Vellore -	224,219	6,51,961	54,102	2,12,331	—	—	—	—	—	—	—	—	—	—	—	—	170,117	4,39,630
Cuddapah -	226,805	7,34,849	—	—	—	—	—	—	—	—	—	—	—	—	—	—	226,805	7,34,849
Kurnool -	54,737	2,63,692	—	—	—	—	—	—	—	—	—	—	—	—	—	—	54,737	2,63,692
Bellary -	163,632	6,83,829	—	—	—	—	—	—	—	—	—	—	—	—	—	—	163,632	6,83,829
Chingleput	352,693	8,09,016	7,571	19,176	—	—	—	—	—	—	—	—	—	—	—	—	345,122	7,89,840
North Arcot	262,898	11,37,863	21,291	1,19,873	—	—	10,993	50,275	2,621	10,485	3,712	18,527	327	1,211	17,653	80,498	223,954	9,37,492
South Arcot	389,414	16,87,296	No information available.		108,519	7,09,821	—	—	—	—	—	—	—	—	—	—	280,895	9,77,475
Salem - -	105,708	4,82,414	—	—	—	—	—	—	—	—	—	—	—	—	—	—	105,708	4,82,414
Coimbatore	103,383	5,57,357	—	—	49,728	3,68,086	35,039	1,69,008	1,146	4,416	928	2,368	138	190	37,251	1,75,982	16,404	13,289
Tanjore -	944,573	37,12,975	796,968	34,49,496	—	—	—	—	—	—	—	—	—	—	—	—	147,605	2,63,479
Trichinopoly	206,376	7,79,685	—	—	—	—	—	—	—	—	—	—	—	—	—	—	206,376	7,79,685
Nilgiris -	40	90	—	—	—	—	—	—	—	—	—	—	40	90	40	90	—	—
Malabar -	388,309	11,60,266	—	—	—	—	—	—	—	—	—	—	388,309	11,66,266	388,309	11,66,266	—	—
Madura -	182,157	6,55,546	—	—	—	—	—	—	—	—	—	—	—	—	—	—	182,157	6,55,546
Tinnevelly -	204,894	15,00,612	30,019	1,58,657	—	—	—	—	—	—	—	—	—	—	—	—	174,875	13,41,955
Total -	5,155,866	1,93,63,632	1,680,178	73,97,776	166,454	11,20,621	60,295	2,73,997	34,228	1,36,440	6,080	27,236	390,801	11,68,853	491,404	16,06,526	2,817,830	92,38,709

Parliament, dated the 11th of May 1858, for the purpose of constructing and managing works of irrigation and navigation in various parts of India. An indenture or contract deed was executed on the 3rd of June 1863 between the company and the Secretary of State for India, providing for the execution by the company of one work to be selected by the Local Government, to cost one million sterling, and on which 5 per cent. return was guaranteed by the Secretary of State. In pursuance of that agreement, the so-called Toombudra or Tongabudra project was adopted. This included a canal for irrigation and navigation from Sunkesala, 17 miles above the town of Kurnool on the Toombudra, to the Kistnapatam estuary on the sea-coast in Nellore. The company accordingly undertook that section of the scheme which extends from Sunkesala to Soomaisweram on the Pennar river.* In 1866 it having been found that the original estimate was quite insufficient to complete the project, a further agreement was concluded on the 30th of July of that year. This contract separated the section of the scheme extending from Sunkesala to Cuddapah from the remainder of the project, and provided for a loan of six hundred thousand pounds from the Secretary of State to the company on the security of debentures issued by them. The loan was to be expended in the completion of the canal to the Pennar and thence to the town of Cuddapah. The work was virtually completed in 1871.

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* Annual Progress Report of the Irrigation Branch, Madras Presidency, 1877-78.

A great deal of correspondence* passed in 1871 between the Governments of India and Madras with reference to the company. It appeared doubtful if the conditions imposed on the company that the canal was to be in "perfect working order to the satisfaction of the Local Government by the 1st of July 1871" had been carried out, and it was contemplated to take over from the company all their works and to carry them on by direct Government agency. At about the same time the company applied for an extension of their guarantee for the purpose of completing what they termed their "original Toombuddra project." In July 1871 Captain Scott, R.E., reported on the works for the information of Government; he reported 189 miles of main canal and 216 miles of distributaries to be practically completed, the area then commanded being 91,567 acres. There appeared to be great fears that the banks and retaining walls would breach; Captain Scott, indeed, expressed an opinion that many breaches would occur if the canal were tested by a full irrigation supply for thirty days. Probably this would be the case in almost any new canal when it was first opened, but great stress seems to have been laid on the fact to the prejudice of the company. In 1872 the Government of Madras reported that "it seems doubtful whether in their present state the works can prove remunerative, for 130,000 acres must be irrigated to pay the interest alone on the capital expended, while the largest extent of land actually irrigated hitherto by the works has only been 1,887 acres. Works which were originally estimated to cost four hundred and ninety-three thousand three hundred and forty-eight pounds are said to have actually cost one million fifteen thousand five hundred and fifty-two pounds, and serious strictures were passed on the details of construction of the works. In consequence of this report the Secretary of State informed the company on the 9th of January 1872 that* "the practical conclusion to which his Grace, in common with the Governments of India and Madras, has come, is that no public advantage whatever, but, on the contrary, very serious disadvantage, has accrued from the recourse which for so many years continuously has been had to the co-operation of the company in the construction of irrigation works; and he sees no reason for supposing that anything would be gained by either the Government or the people of India from further perseverance in the same course. He desires it, therefore, to be distinctly understood that in any further operations which may be contemplated by the company, they must rely entirely on the resources which they can independently command, for that no further pecuniary aid in any shape will be afforded by the Government." However, the Government did not exert their right to acquire the works of the company and manage them themselves.

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* Correspondence, printed by order of the House of Commons, between the Secretary of State for India and the Governments of India and Madras, May 1872.

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* Correspondence, printed by order of the House of Commons, between the Secretary of State for India and the Government of India and Madras, May 1872.

The company still carried, and still continues to carry them on with results which are very far from satisfactory.

In 1876 arrangements were made between the company and the Secretary of State, whereby the former abandoned all parts of their scheme outside the Sunkesala and Cuddapah canal on condition of receiving a refund of the expenditure incurred by them on the investigation, &c. of the projects so abandoned. Hitherto the canal had been a failure in a financial point of view. The returns from irrigation and the sale of water generally have been insignificant when compared with the capital outlay. They averaged to the end of 1875–76 about fifty-one thousand rupees per annum, but the impetus given to irrigation in the following years by the failure of the monsoon rains raised the revenue receipts very materially.

It has been alleged that the postponement of the arrangements necessary for opening the canal for navigation—a postponement due to the company being without the necessary capital to allow of the navigation works being completed and floating plant provided—acted prejudicially against the extension of irrigation.

The statement on page 28 is given in the Madras Progress Report, 1877–78, as the present estimated cost of the works, but it is evidently not complete.

This estimate does not include items for the Home expenditure and establishment; the total amount expended on the works up to the end of 1877–78 was one million seven hundred and eight thousand two hundred and eleven pounds sterling.

Works.		Estimated Cost.
		£
Anicut and Headworks at Kurnool		30,308
One mile of Canal from Anicut		6,500
Anicut and Headworks at Sunkasala		48,932
1st Section Main Canal, 18 miles		112,978
Aqueduct across the river Hindry		48,065
2nd Section Main Canal, 14 miles		202,458
3rd do. do. 11 do.		99,086
4th do. do. 17 do.		121,063
5th do. do. 12 do.		89,188
6th do. do. 19 do.		94,639
7th do. do. 23 do.		76,699
8th do. do. 28 do.		83,839
9th do. do. 35 do.		96,211
Anicut and Headworks at Adimapally		43,823
10th Section Main Canal, 18 miles		25,726
Anicut and Headworks at Soomaisweram		17,172
Distribution Works		34,327
Buildings		10,626
Breach repairs of August 1870		6,244
Line of Telegraph from Sunkesala to Cuddapah		7,203
Revenue Account		22,998
Navigation		38,454
Total		1,296,439
Deduct—		
	£	
Retrenchment from 4th Section, Main Canal	12,487	12,726
Retrenchment from 4th Section, Buildings	239	
Total		1,283,713

The canal begins* at Soonkesala with a weir across the river Toombuddra. The weir has a length of 1,500 yards of clear overfall, but is broken into two parts by an intervening island. The weir stands upon the rocky river-bed, and is formed partly of solid rubble masonry of gneiss trap and quartzite boulders, partly of gravel concrete with gneiss rubble facing in front and rear of the same section, and partly of solid gneiss rubble masonry, with a facing on the lower side of Kurnool limestone ashlar. The coping is joggled wherever the anicut (which is not straight, but follows the line of the highest solid rock) is concave in plan on the up-stream side. The height varies from 6 to 26 feet, and averages about 18 feet, and the highest registered flood rose 7½ feet over the crest.

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* "The Soonkesala Canal of the Madras Irrigation and Canal Company," by J. H. Latham, M.A., M.I.C.E. Proceedings of the Institute of Civil Engineers, vol. xxxiv.

From the Soonkesala weir the water is admitted into the canal by a head-sluice without any lock. The face of the head-sluice is kept clear by the scour of ten under-sluices at a lower level in the weir, the stream to these under-sluices is forced against the front of the head-sluices by a long curvilinear groin. The minimum cross-section of the canal for the first seventy-five miles has a 90-feet bottom, with 2 to 1 side-slopes, the depth of water being 8 feet. Below the forty-fifth mile, the canal being in good soil, a depth of 9 feet of water is allowed. At the seventy-fifth mile the canal passes through the watershed between the Toombuddra and the Pennair rivers at Metacondal; and thence the natural watercourse becomes the main supply channel under the successive names of the Kali, the Koonder, and the Pennair.

The canal in the first seventy-five miles is calculated to carry 3,000 cubic feet of water per second, and, after gradually parting with about 750 cubic feet per second for irrigation, to convey at least 2,250 cubic feet per second through the Metacondal cutting. At Metacondal 1,915 cubic feet per second may be discharged into the Kali, and 337½ cubic feet per second carried down the continuation of the canal. Of the 1,915 cubic feet per second poured into the Kali, the canal is calculated to take up 750 cubic feet per second at Jutoor, and 375 cubic feet at Rajoli, leaving about 750 cubic feet of water per second for the irrigation below Cuddapah and for Nellore.

From the natural main supply channels into which the first section of the canal discharges at Metacondal the water is taken at four points, viz. Lockinsula, Jutoor, Rajoli, and Adanimayapilly, by the simple process of throwing weirs across it, with the under-sluices in the weirs to keep down the silt, and head-sluices across the channel to control the supply and entrance locks.

The canal may be divided into five sections:—

1st. The section from the head at Soonkesala to the seventy-fifth mile, when the canal joins the Kali. This length distributes one-fourth of its supply, which it draws from the Toombuddra, over the country, and throws the remainder into the natural water-courses of the Kali, to be drawn off with the other channels as it is required.

2nd. The section from the seventy-fifth to the ninety-fifth mile. This length is an irrigating channel for six miles only. It carries only 337½ cubic feet per second out of 2,250 cubic feet which the first channel had discharged into the Kali. From the end of the sixth mile this channel is a still-water canal, 45 feet base, and having a minimum depth of 5 feet. But the head-sluice and lock are designed for 6 feet of water if the extra supply is ever required. The canal in this twenty miles drops 180 feet 5 inches through twelve locks. At the ninety-fifth mile the channel tails into the next length.

3rd. The section from the ninety-fifth to the one hundred and forty-sixth mile. This length draws off its supply, which the Kali watercourse carries down from the end of the first channel, from that watercourse at Jutoor. It is intended to distribute 750 cubic feet per second in the district of Kurnool. The headworks consist of a weir of limestone in rubble masonry founded on soft shale: the weir is 6 feet broad below the coping, and has a batter on the upper side of 1 in 4; the rear face, which is ashlar, descends vertically into a trench or water-cushion hollowed out of the shale and lined with limestone masonry. This channel is designed for 6 feet of water; it is an irrigation channel for 23 miles only of its length. From the one hundred and eighteenth mile to the one hundred and forty-sixth it consists of level reaches, which fall 187½ feet through seventeen locks; the base of the canal is 50 feet. The last lock on this length drops the canal into the next, or fourth section.

4th. This fourth length of canal is, like the two former ones, supplied from the same watercourse into which the first channel discharges at its tail. The watercourse is called the Koonder at the place, called

Rajoli, where the head of this channel is fixed. The one hundred and forty-sixth mile of the navigable canal drops into this channel at about a quarter of a mile from its head. The headworks consist of a weir across the Koonder of rubble masonry 5 feet thick at the top, with a batter of 1 in 2 on the upper face, and plumb on the lower face. The weir is built on solid limestone-rock. This channel is an irrigating one as far as the one hundred and seventy-second mile only; from thence to the one hundred and eightieth mile, where it falls into the same watercourse, it is a navigation canal only in level reaches. It falls 90 feet 6 inches in its length, and is calculated to carry 375 cubic feet per second in the first 26 miles only. The base is 50 feet.

5th. The fifth and last section of the canal is only 8 miles long. It supplies a very small area with water. It is, in fact, the first eight miles of the proposed canal into Nellore. There are headworks across the Pennair very similar to those of the other channels. The canal terminates at the end of this length, about one and a half miles from the Madras railway, and 163 miles from Madras itself.

The locks on this canal are 120 feet long by 20 feet broad in the clear, with a working depth of 5 feet 6 inches of water. The headway allowed under the bridges is 15 feet. A large aqueduct carries the canal over the Hindry by fourteen arches of 40 feet span. The most remarkable feature in this canal is the height of many of the embankments and the method of their construction. There are 8½ miles of embankment, where the water-level of the canal is more than 35 feet above the level of the country. In two miles the bank exceeds 40 feet in height, and it even reaches 50 feet. These banks are made in many different ways, and a full and most interesting account of them will be found in the paper quoted in the footnote of p. 28, from which this account of the works is mainly derived. The largest banks are made with a masonry face wall backed by a quartzite gravel bank 6 feet wide at the top, with an outer slope of 2 to 1. The face wall is perpendicular at the back, with a batter of 1 in 7 in the front; it is 2 feet thick at the top, strengthened by counter-forts 16 feet apart. In parts the banks are formed with puddle cores, 9 feet thick, on each side of which rubble-stone is packed; the inner face of the slope is lined with puddle 3 feet thick. The puddle is protected by dry rubble-packing on the face, and at the toe of the slope it is worked into a trench 5 feet deep. Many varying arrangements of puddle and pitching and different forms of face walls and revetment walls are used in different parts.

The canal is said to command 183,300 acres of land for irrigation.

CHAPTER III.

THE IRRIGATION WORKS OF BOMBAY.

Classification.—Mutha Canals.—Jamda Canals.—Krishna Canals. Lakh Canal.—Palkher Canal.—Ekruk Tank.—Hathmati Canal. Bhatodi Tank.—Maini Tank.

THE irrigation works of Bombay may be divided into four great classes as follows*:—

Class I. Works fed from rivers rising in the western ghats, the supply to which is rendered permanent by storage.

Works of this class have a certain supply lasting all the year round. The only work fulfilling these conditions yet brought into operation is the Mutha canal.

Class II. Works fed from rivers supplied from the western ghats unaided by storage.

Works of this class have a certain supply lasting from June to December only.

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* Irrigation Revenue Report of the Bombay Presidency, 1877-78.

Class III. Storage tanks on, and canals fed from, rivers, with extensive catchment areas, not rising in western ghats.

The supply to works of this class depends on the local rainfall, and is variable and uncertain.

Class IV. Storage tanks on, and canals fed from, rivers with restricted drainage areas.

The supply to works of this class is the same as Class III., but still more variable and uncertain.

The table on p. 36 shows the chief works appertaining to each class, the area under command, and other statistics concerning the canals.

The following information concerning these canals is taken from the Revenue Report of Bombay for 1876–77, which gives a very full account of all the works.

Mutha Canals.

This scheme was first proposed by Colonel Fife, R.E., in 1863–64, after a protracted investigation of proposals for the irrigation of the district east of Poona by small tanks on the tributary streams, which were proved to be financially impracticable.

The Mutha river, a tributary of the Bhima, rises in the western ghats, 30 miles from Poona, and by locating the headworks of the canal on that river, a certain and unfailing supply—during the four months over which the south-westerly monsoon lasts—was secured. The rainfall on the ghats is seldom less than 200 inches, and has never been known to fail. Plans and estimates for the project were finally submitted

Works.		Source of Supply.	Miles of Main and Branch Canals.	Approximate Annual Rainfall.	Discharge at Head in Cubic Feet per Second.	Average Area irrigated by the Canal during the last five years.	Area actually irrigated in 1877-78.	Actual Cost of Works to 1877-78 without Interest.	Total * culturable Area under Command. 1878.	Population per square mile in 1872.	Kind of Canal.
BOMBAY.					cub.ft.	Acres.	Acres.	£	Acres.		
Mutha Canals.	Class I.	Mutha River	140	27·41	450	1,651	5,361	584,956	38,571	178	Intermittent.
Jamda Canal	Class II.	Girna River	45	25·53	382	1,510	4,924	102,741	39,680	101	Chronic.
Krishna Canal		Krishna River	45	26·20	140	2,500	2,934	89,016	20,823	208	Chronic.
Lakh Canal		Prawara River	38½	21·50	182	604	1,540	36.349	22,002	116	Chronic.
Palkher Canal		Kadwa River	11	22·50	80	481	1,076	22,659	19,638	90	Chronic.
Smaller Works		- - -	- -	23·23	—	* 341	447	62,344	19,267	180	Chronic.
Ekruk Tank	Class III.	Adhila River	48	23·37	—	1,032	1,837	140,900	17,406	169	Intermittent.
Hathmati Canal		Hathmati River.	20	28·00	450	*	1,043	55,510	34,068	216	Intermittent.
Bhatodi Tank	Class IV.	Mekhri River	4½	23·10	—	358	554	38,272	9,650	116	Tank.
Maini Tank		- - -	- -	26·00	—	*	983	39,464	4,459	208	Tank.
Smaller Works		- - -	- -	20·50	—	*52	87	46,163	7,395	162	
								1,218,374	232,959		

* These have not all been in operation for five years.

in 1868, and in December of that year these canals were commenced.

The scheme comprises a large storage reservoir or lake on the Mutha river, 10 miles west of Poona, with two canals, one on each bank of the river. The canal on the right bank is designed to be 99½ miles long, and to discharge 412 cubic feet per second at the head. The discharge can, if necessary, be increased to 535 cubic feet. The canal passes through the station of Poona, and is designed to command 230 square miles, or 147,200 acres of land, nearly all of which is situated east of Poona. This area lies entirely in the dry zone of the Deccan, which is described by General Strachey as a band running parallel to the line of the ghats, and at a distance of about 20 or 30 miles to the east of them, along which the rainfall seldom exceeds 20 inches. In this zone the variations in the rainfall and risk of severe drought are great in proportion as the absolute rainfall is small. The left-bank canal is 14½ miles in length, and extends a short distance beyond the station of Kirkee. It commands an area of 4,300 acres, and the designed discharge at the head is 38·5 cubic feet per second. The total area to be commanded by the complete scheme is thus 151,500 acres.

Besides providing for the irrigation of this tract, the work is designed to furnish an abundant supply of pure drinking-water to the city, cantonment, and civil station of Poona; also to the powder works at Kirkee, and to the numerous villages situated along the course of the canals.

The reservoir is formed by a masonry dam founded on solid rock. The dam is of uncoursed rubble masonry, and is one of the largest works of its kind in the world. Its length, exclusive of the waste weir (which is 1,453 feet long), is 3,683 feet, and the height above the river-bed is 99 feet, the maximum height above the foundation-level being 107 feet. The crest of the waste weir is designed to be 11 feet below the top of the dam, and the maximum depth of storage is thus 88 feet. The contents of the reservoir, when completed, will be 5,226,000,000 cubic feet, and the area of the water surface will be 3,681 acres, or 5¾ square miles. In order to gain sufficient elevation to command the station of Poona and district beyond, the level of the bed of the canals is fixed at 59 feet above the river-bed, or bottom of the reservoir. The available depth of storage is thus 29 feet. The volume of water stored above the canal-level is 3,476,000,000 cubic feet. The river at the site of the dam has a catchment area of 196 square miles. During an average season it is calculated that the reservoir will fill sixteen times, and that one-sixth of the whole discharge of the river will be turned to account. Provision is made for the utilisation of the water-power available at the reservoir. The water will be passed through turbines into the canal, and it is calculated that it will develop to constant force of eighty horse-power.

The right-bank canal is navigable as far as Poona. In the tenth mile the water-supply for the city is drawn off. The canal is carried through the station of Poona in tunnel to avoid interference with the buildings, parade-ground, &c. There are two tunnels. On emerging from the first, in the centre of the cantonment, the canal-bed falls. This fall is utilised, by means of an undershot wheel, to drive pumps for raising the water into the settling-tanks, filter-beds, and covered dispense-reservoirs of the high and middle service systems. From the canal itself low service mains and branches are led off.

Under the instructions of the Government of India, the length of the right-bank canal is to be restricted for the present to the seventy-first mile, up to which point the area under command is 98,384 acres, including that on the left bank. The total estimated cost of the works is six hundred and thirty-six thousand five hundred and eighty-nine pounds. Of this it has been estimated that the portion debitable to the water-supply of Poona is sixty-seven thousand five hundred and sixty-three pounds, leaving five hundred and sixty-nine thousand and twenty-five pounds as the cost of the irrigation scheme including mill-power. Deducting for the latter item seven thousand four hundred and ninety eight pounds, the net cost of the irrigation scheme is five hundred and sixty-one thousand five hundred and twenty-seven pounds. The area under command is 98,384 acres, and the cost per acre is thus five pounds fourteen shillings. This will be reduced, if the canal is extended as originally designed to command 151,500 acres, to four pounds per acre, including the cost of extension. The total cost of the works to the end of 1877–78 was five hundred and eighty-four thousand nine hundred and fifty-six pounds.

Jamda Canals.

The Girna river, on which these canals are situated, is a tributary of the Tapti. It rises in the western ghats, 60 miles west of Malegaon; at Jamda, the headworks of the canal, it has a drainage area of 2,700 square miles.

This is the first work of any magnitude which was undertaken in the Deccan by the Indian Government; the plans and estimates were drawn up in 1863. They provided for a masonry weir, 1,540 feet in length and 18 feet in maximum height, founded on solid rock across the Girna river, near the village of Jamda, in the Khandesh collectorate, with two canals—one on the left bank, 27 miles long, commanding 25,600 acres; and one on the right bank, 18 miles long, commanding 12,100 acres. The canals traverse portions of the Chalisgaon and Pachora talukas. The works have been constructed as designed, with the exception that the tail portion of the right-bank canal, 6 miles in length, has been omitted, whereby the total area under command has been reduced to 30,000 acres. The left-bank canal has a discharge capacity of 261 cubic feet per second at the head, and that on the right bank 121 cubic feet.

Work was commenced in 1863, and a section of the left-bank canal, 10 miles in length, was opened in

February 1866. The scheme was designed principally for monsoon irrigation.

The left-bank canal has been in operation for eleven years. That on the right bank was not brought into operation until the year 1877–78, owing to there being no demand for monsoon or rabi water, and to the perennial supply being insufficient. This canal is capable of extension to command a large area of land in the adjoining valley of the Boree river, and the aqueducts and bridges have been constructed to admit of an increased discharge. The headway to over-bridges is sufficient to admit of navigation. The capital outlay to the end of 1877–78 was one hundred and two thousand seven hundred and forty-one pounds.

Krishna Canal.

The headworks of this canal are situated on the top of a rocky barrier across the Krishna river at Korsee, 2 miles above the town of Karad at the confluence of the Koina and Krishna rivers. The Krishna river rises in the western ghats and at the site of the canal headworks drains an area of 1,247 square miles. The project, as drawn up and sanctioned in 1863, comprised a weir of rubble masonry 1,200 feet in length and 21 feet in maximum height, with a small subsidiary weir to retain a pond of water to break the force of the water falling over the main weir during floods, and a canal 45 miles in length commanding 44,800 acres on the left bank of the river.

Pending experience as to the extent to which rice and monsoon crops were likely to be irrigated, the length of the canal has been restricted to 32⅛ miles. The culturable area under command is 20,823 acres. The canal is calculated to discharge 140 cubic feet per second, generally, for eight months in the year; but in order to take advantage of freshes its escapes and embankments were designed at such a level as to secure as much as 300 cubic feet per second whenever such a supply might be available. Provision was also made for constructing, at the close of the monsoon, a temporary earthen bank on top of the weir, with escapes at each end, in order to store the water brought down by the slight freshes, which generally occur in April and May.

Provision has been made for deepening the canal at the head, should it prove that the perennial supply requires to be supplemented, by drawing off the water stored above the weir to a lower level.

The work was opened for irrigation during the rabi season of 1868. In 1872 a complete system of main distributaries was sanctioned; these have since been constructed as required. The work was estimated to irrigate 27,500 acres. The capital outlay had been eighty-nine thousand and sixteen pounds to the end of 1877–78.

Lakh Canal.

The headworks of this canal are situated on the Prawara river. The scheme was commenced in October 1866. It consists of a masonry weir, founded on solid rock across the Prawara river, 1,500 feet long and 15·5 feet in maximum height, with a canal 21½ miles in length which traverses portions of the Rahuri and Newasa talukas on the left bank of the river. At the tail the main canal bifurcates into two branches, the length of which is 17 miles. These, with 19 miles of distributing channel, command the whole area lying between the Prawara and the Godavari at their junction, which is described as a fine black-soil plain The area under command is 25,000 acres; the canal has a capacity of 182 cubic feet per second at the head. At the weir site, the river has a catchment area of 909 square miles. A first section, 3 miles in length, was opened on the 15th of March 1868. A further length of 2 miles was opened in the following June, and water was passed along the whole length of 21 miles in August 1869. The tail distributaries were not, however, commenced until 1872–73. The works were entirely complete, with the exception of masonry heads to distributing channels, in 1873–74. The capital outlay had been thirty-six thousand three hundred and forty-nine pounds up to the end of 1877–78.

Palkher Canal.

The Kadwa river, from which this canal is supplied, rises in the western ghats, 30 miles north of the town of Nasik, and joins the Godavari, 20 miles east of that place. The headworks of the canal are formed by a weir of rubble masonry, 20 feet in height, and with a length of crest of 800 feet, situated on a rocky barrier about 20 miles above the junction of the rivers. The Kadwa river drains an area of 332 square miles, above the weir site. The canal is on the right bank of the river, and commands the whole area lying between the Kadwa and Godavari immediately above their junction. This area is 20,000 acres, and comprises twenty villages of the Dindori and Niphar Talukas of the Nasik Collectorate. The canal has a discharge capacity, at the head, of 80 cubic feet per second, and is 11 miles long, with main distributaries 8 miles in length. The plans and estimates were drawn up and the works commenced in 1868, but their progress was delayed by two accidents, due to excessive floods, and the canal was not opened for irrigation until the kharif season of 1873–74, when the work was only partially complete. The main canal was not entirely completed until 1875–76, and the distributaries and their masonry heads are still unfinished. The capital outlay up to the end of 1877–78 was twenty-two thousand six hundred and fifty-nine pounds.

The smaller works of Class II. are :—

In Nasik, the Wadali canal from the Kadwa river.
In Ahmednagar, the Ojhar canal from the Prawara river.
In Satara, the Rewari canal from the Wasna river.
In Satara, the Yerla canal from the Yerla river.
In Dharwar, Madag tank on the Choardy river.

The Wadali is an old canal which has been improved and extended.

The Ojhar canal is a small work commanding only

4,408 acres. The canal is 10 miles in length and carries 125 cubic feet per second.

The Rewari canal was originally partially constructed about the year 1871 by one Naroo Appaji, who held high office in the service of the Peshwa. The weir across the river was completed, but the canal was in an unfinished state when he died, and the work was not completed. After the district passed into the hands of the Indian Government, some expenditure was incurred in bringing the unfinished work into operation, and it is said the canal was used for irrigation one year, but owing to the want of slope in the channel, and to its being carried under two of the drainage channels in tunnels of insufficient capacity to admit of their being cleared, it was found impossible to keep the water running, and after one season's experience the work was abandoned. In 1863 the work was undertaken by the Government, the channel leading from the weir was reconstructed and the canal, which is 4 miles in length, put in good repair. It commands 6,004 acres, of which 5,341 are culturable.

The Yerla canals consist of two channels, one on each bank of the river Yerla. The one on the right bank is 9 miles long, that on the left 8¼ miles. The area under command is 12,800 acres, but the supply of water available is only sufficient to irrigate 6,500 acres during four months in the year.

The Madag tank is an old work in the extreme south of Dharwar on the borders of Mysore. It is reported to have burst when it was first made by the natives, who were afraid to complete it after the accident. Two canals are led off from the tank which at present only command 2,467 acres of culturable land.

Ekruk Tank.

This work, one of the largest of its class, undertaken by the Indian Government, is situated 5 miles north-east of Sholapur; the scheme was drawn up in 1863 and sanctioned in 1866. It comprises a reservoir or tank formed by an earthen dam, and three canals for irrigation. The dam is 7,000 feet in length and 76 feet in maximum height, thrown across the valley of the Adhila river, a tributary of the Lina. The drainage area of the river above the tank site is 160 square miles. The tank is 60 feet deep when full, and contains 3,350,000,000 cubic feet. The area of the water surface is 4,640 acres, or 7¼ square miles. Two waste weirs, of an aggregate length of 750 feet, are provided for the escape of flood-water after the filling of the tank. There is one canal on each bank of the river at a high level, designed for four months' irrigation, and a third, on the left bank, at a low level, designed to give a perennial discharge. The table on p. 47 gives the length and capacity of each canal, and the areas under command.

The low-level canal flows close past the town of Sholapur. The high-level left-bank canal is capable of extension to command an additional area. The same may be said of the other two canals, but not to a proportionate extent. The scheme was estimated to furnish a supply sufficient for 21,150 acres of irriga-

Canal.	Length.	Carrying capacity, Cubic Feet per Second.	Level at which Canal takes off below full supply level in the Tank.	Area under Command.
	Miles.		Feet.	Acres.
High-level right bank canal.	18	60	14	6,476
Low-level canal (left bank).	26	70	39	10,444
High-level left bank canal.	4	25	14	826
Total . .	48	155	—	17,746

tion annually. The work was commenced in 1866–67, and the dam was closed—a work of some risk with so high a dam—in December 1869. The scheme was brought into partial operation during the kharif season of 1871–72. At the end of 1876–77 the work was entirely completed, with the exception of the last two miles of the low-level canal, and of the last twelve miles of the right-bank canal. The capital outlay has been one hundred and forty thousand nine hundred pounds to the end of 1877–78.

Hathmati Canal.

The Hathmati river is a tributary of the Salarmati. The headworks of the canal, which takes its name from the river, are situated in Edar territory, just above the old fortified town of Ahmednagar, about 40 miles above Ahmedabad. At the site of the headworks of the canal, the river has a drainage area of 524 square miles. The canal is 20 miles long and commands an area of 34,068 acres on the left bank of the river. For the first three miles of its course it is in Edar territory, and thence to its tail, where it joins the Khari river, it traverses a portion of the Ahmedabad collectorate.

Plans and estimates were first drawn up in 1869. They provide for a total length of 32⅜ miles of canal, commanding 45,068 acres. For the first 5¼ miles the carrying capacity was 450 cubic feet a second, and provision was made for discharging 250 cubic feet a second into the Bujwah, a tributary of the Khari, to supplement the supply in the latter river, which is utilized some miles lower down by a system of sluices. It was found, however, that the constant reliable supply in the Hathmati river, at different seasons, had been over-estimated; and the length of canal was, therefore, reduced to 20 miles.

The headworks of the canal are formed by a weir of rubble masonry 1,000 feet long, and 22 feet in maximum height. The work was commenced in 1869–70 and was brought into partial operation in 1873–74. The outlay to the end of 1877–78 was fifty-five thousand five hundred and ten pounds.

Bhatodi Tank.

The capital cost of this work, amounting at the end of 1877–78 to thirty-eight thousand two hundred and seventy-two pounds, comprises the expenditure incurred on the restoration of a ruined tank, believed to be many centuries old, situated on the Mekhri river which rises 10 miles north-east of the town of Ahmednagar, and joins the Sina river 40 miles below Ahmednagar. Unlike most native works of the kind, the dam consisted, where it crossed the river-bed, of a low massive masonry wall some distance in front of the line of earthen embankment, which formed the principal portion of the dam. The work, as taken in hand by the English Government in the early part of 1868, comprised the completion of the masonry dam, 2,400 feet long and 50 feet in maximum height; the construction of a waste weir on the left bank, 450 feet long with its crest 7½ feet below the top of the dam; and of a canal for irrigation on the right bank, 4½ miles long, capable of discharging 140 cubic feet per second at the head, and commanding altogether 14,000 acres of land. The land under command is situated in eight villages of the Ahmednagar Taluka. The level at which the canal takes off is 22½ feet below the crest of the waste weir. The drainage area of the tank is 50 square miles. The tank has an available capacity of 149,000,000 cubic feet, and an area when full of 310 acres. It is estimated to fill with a rainfall of 5·40 inches, of which half an inch runs off.

The work was partially completed and open for irrigation in 1871. In that year the tank was filled to a depth of 10 feet; any water over that depth was allowed to escape through a gap 95 feet long left in the masonry dam; it had a vertical drop of 25 feet. In 1871–72 the dam was raised a further height of 5 feet, and a cistern to break the force of the falling water was added. The storage was thereby increased to 108,000,000 cubic feet. Before the monsoon of 1876 the dam was raised a further height of 2½ feet, and entirely completed before the end of 1876–77.

Maini Tank.

This work is situated on a small tributary on the left bank of the Yerla river, 22 miles south-east of the Yerla canals, and 45 miles from Satara. The scheme was first investigated in 1866. The plans and estimates were sanctioned and work commenced in 1868. The work comprises a storage reservoir, capable of containing 190,000,000 cubic feet, and having an area, when full, of 380 acres, formed by an earthen dam 2,870 feet long and 57 feet in greatest height, constructed across the valley of the Wang river. The catchment area of the river above the dam is 54 square miles. The level at which the canal takes off is 31 feet below the waste-weir crest. The canal has a discharge capacity at the head of 33 cubic feet per second. The work was designed to command in all 7,000 acres, but up to the end of 1876–77 the actual area under command was 4,638 acres, of which 4,459 were culturable, and were comprised in three villages of the Khatar and Khanapur talukas.

The smaller works under Class IV. are:—

The Hartala tank in Khandesh.
The Mhasra tank in Khandesh.
The Kasurdi tank in Poona.
The Koregaon tank in Sholapur.
The Gondoli canal from the Man river in Satara.
The Chikli canal from the Nandni river in Satara.
Kalala dam across the Kalala Nulla in Dharwar.

These are all small works of the same nature as the larger ones previously described. Some of them are new works undertaken by the English Government, and some are old native works restored.

CHAPTER IV.

THE IRRIGATION WORKS OF SIND.

Indus Delta.—Inundation Canals.—Sind.—Ghar.—Western Nara.—Begari.—Eastern Nara.—Fuleli.—Sukkur and Shahadadpur.

THE rainfall in this province averages about 9 inches. Here the very existence of the people is entirely dependent on the canals; those parts which are without an artificial supply of water are barren, uncultivated and unpopulated. The canals are mainly old native works which have been restored, improved, and maintained by the British Government. The statement on p. 53 gives such statistics as are available of the principal canals in Sind.

The following account of the canals is taken from the parliamentary paper mentioned in the foot-note.* It is much to be regretted that no more detailed account of these very interesting works is available.

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* Statement of the Moral and Material Progress and Condition of India, 1872-73.

Works.	Source of Supply.	Miles of Main and Branch Canal completed in 1878.	Approximate annual Rainfall.	Average Area irrigated by the Canals during the last three years.	Area actually irrigated in 1877-78.	Actual Cost of Works to 1877-78 without Interest.	Population per square Mile in 1872.	Kind of Canal.
SIND.								
Works in Operation.				Acres.	Acres.	£		
Desert Canal - -	Indus	52	No detail available. The rainfall in the Province averages about nine inches	45,665	44,112	58,011	47	Inundation.
Fuleli Canal - -	,,	1,147		166,013	135,497	111,798	80	,,
Great Marrack Canal	,,	3,129		558,144	478,025	17,574	55	,,
Surfrazwah Canal -	,,					12,441		
Western Nara - -	,,					28,671		
Eastern Nara - -	,,	214		114,810	102,402	323,881	14	,,
Ghar Canal - -	,,	510		384,146	293,981	43,165	88	,,
Begari Canal - -	,,	147		108,204	76,198	112,382	47	,,
Sukkur, Sind, & Shahadadpur Canals.	,,	428		171,465	136,839	126,081	88	,,
		5,627		1,548,447	1,267,054	834,004		

After the rivers of the Punjab unite in the Indus at Mithankot, that river flows for 450 miles to the sea, through the arid and rainless country of Sind. What the monsoons are to other parts of India, the inundation of the Indus, and the canals which distribute its waters, are to Sind. This country is an alluvial plain, almost every portion of which has been swept by the Indus, or its branches, at some time or other. Traces of ancient channels are to be met with in almost every direction. The land is highest at the river-banks, and slopes away on either side. The reason of this is that the river brings down a greater quantity of silt than its stream, moderated in velocity on the nearly level plain, can carry forward. The silt is deposited, and the result is that the bed and banks of the Indus are continually rising. The process is sure, but very slow. Dr. Lord calculated that the Indus annually brings down silt sufficient to form an island 42 miles long by 27 broad, and 40 feet high. When the bed attains a certain height the water spills over the banks, and the river, at intervals of several centuries, changes its course. It has slowly worked its way from east to west. In A.D. 710 the invading Muslims found a Hindu dynasty at Alor. The ruin of Alor was caused by the Indus moving to the west. Then the seat of government was moved to the city of Brahmanabad, the ruins of which are now 45 miles from the river.

It is this movement of the river which causes one of the difficulties in Sind irrigation. The river is continually carrying away the banks in one direction, and forming new land in another. This process never ceases; the falling masses of earth make a noise in the distance, resembling volleys of musketry. From Sakhar to the sea the distance is 300 miles; the banks are permanent only at three places, Sakhar, Jhirk, and Kotri. At Sakhar the river rushes through a narrow gorge in the limestone hills, forming a perfect rapid during the inundation, with a descent of above 4 feet. At Jhirk the river is not contracted, but there is rock on either side. At Kotri hills approach on both sides, and the clay soil is deep and tenacious. The rise of the Indus commences in May and subsides at the end of August.

The canals are excavations carried away from the river in an oblique direction. They vary from 10 to 300 feet in width, and from 4 to 10 feet in depth. None, in former times, had their heads at the three places where the river-bed is permanent, and none are deep enough to draw off water from the river except during inundations. They resemble natural water-courses more than canals. From the position of the canal-heads they are liable to two evils; either the river encroaches and tears away the banks, or it recedes and forms a great sandbank across the head.

The canals are cut through the high margin of the river-banks; they conduct the water to lower levels, where, under favourable circumstances, it flows out on the surface. The cultivated land may be divided into three classes—first, the land which can only be irrigated by the help of Persian wheels to raise the water; secondly, land irrigated by machinery, when the canal is low, but over which the water will flow naturally when the canal rises; thirdly, land watered altogether without the aid of machinery. Some of the largest canals were at first natural channels, others were dug by various rulers of Sind. They are rude and simple expedients which attain their object, though less perfectly and at greater cost than if they had been constructed on sound principles. The care of the canal consists in cleaning out the silt deposited by the inundations, or washed away from the sides. This used to be done by statute or forced labour.

On the western bank, commencing from the north of Sind, near Sakhar, the chief canals are the Sind, Ghar or Larkhana, Begari, and Western Nara. All but the Bigari are probably, judging from their tortuous courses, natural channels kept open artificially.

Sind Canal.

The Sind canal opens from the main stream of the Indus, on the right bank, 21 miles below Sakhar. Its total length is 66½ miles, and at its tail it divides into three branches, the Mutti, Kadu, and Mihshuda canals, the former connecting the Sind with the Larkhana canal. The course of the Sind is very tortuous, and the fall deficient.

Ghar Canal.

The Ghar or Larkhana leaves the Indus 23 miles below Sakhar, and has three heads or channels of supply. It is very tortuous, and the fall is thus much reduced. Several smaller canals branch from it; it finally divides into two branches, the Nurwah and Nowrung, and loses its name. The Nowrung again divides into two, the Andrawah and Muldussi, and these are again divided into several smaller channels.

Western Nara.

The Western Nara leaves the Indus 27 miles below Sakhar, and at 40 miles from the head it is 200 to 300 feet wide. This canal is less winding than the Ghar, and the fall is consequently greater. The country is well cultivated on either side of it, and the villages are numerous. It returns to the Indus at Sehwan.

The improvement of these canals, especially of the Ghar, was commenced in 1856 under Captain Ford. A channel of supply was cut from the Western Nara to the Ghar, called the Fordwah, which augmented its supply and raised its level. The head of the Ghar was also much improved. The Fordwah is considered to be one of the most successful works in Sind. It raised the level of the Ghar three feet, and increased its volume enormously, thus converting a large area from wheel to natural-flow irrigation. The lower part of the Western Nara was, of course, somewhat injured, but not in proportion to the gain to the area dependent on the Ghar.

Begari Canal.

The Begari canal, also on the right bank of the Indus, is the most interesting in Sind.

In 1844 it was described by Lieutenant Maclagan as having a total length of 48 miles, with a fall of 35 feet. The head was on a side channel, at a distance of nearly 7 miles from the Indus. For the first 23 miles it passed through a country covered with jungle, but presenting frequent traces of former cultivation. It then entered a district where much water was taken by means of Persian wheels, and towards the end of the forty-eighth mile it became a mere ditch. In 1851, General Jacob, Political Superintendent of the Upper Sind frontier, represented to the Commissioner (Sir Bartle Frere) the great advantage of enlarging the Begari. It was then becoming yearly smaller, from the defective system of clearing. At the head it was 24 feet wide, with a depth of 9 feet. It was proposed to enlarge it to 40 feet, with a depth of 11, and to slope the banks to a proper gradient. The Nurwah was the chief offshot of the Begari, and had been carried far into the desert north of Khangarh. General Jacob in 1852 proposed that the Nurwah should also be cleared and enlarged. He entrusted the work to a native contractor who had to remove enormous heaps of earth, 25 to 30 feet high, to cut away jungle, and to clear dams out of the bed. The contractor did his work well, though only a common Sindhi maistri, and completed it in 1854. The capacity of the Begari was about doubled by the new excavations, and much wheel irrigation was converted into natural flow with a saving each season of thirteen pounds for every wheel. Villages sprang up along the Nurwah, where a few years before people scarcely ventured to take their flocks from fear of Baluch plunderers. Jacobabad was founded in the midst of a barren treeless waste. The water of the Begari canal was brought to Jacobabad, and the tail was extended thence to the Kelat boundary near Khyra Garhi. Now the former desert is a dense forest of babul and other trees, upwards of 60 feet high, sheltering the houses and gardens of the inhabitants. Within a few miles the desert again appears, skirting the Baluchistan hills. It is a level plain of splendid, fertile, alluvial soil, but hard, naked, and barren like a threshing-floor, without shrub, herb, or grass, except in the vicinity of the canals.

Eastern Nara.

On the eastern side of the Indus, between that river and the desert, there is an ancient channel, the Eastern Nara, which had ceased to flow as part of the Indus since that river, deserting the passage through the rocks at Alor, took to its present channel between Rohri and Sakhar. The Eastern Nara had no direct communication with the Indus when Sir William Baker came to Sind in 1842, but received a precarious supply of water from a remarkable depression which runs parallel with the Indus from above Bhawalpur, and, being lower than its flood height, receives some water from canals, and a more considerable volume by direct overflow. The channel of the Eastern Nara being also lower than that of the Indus, can easily be filled from the great river on a higher level, and Sir William Baker pointed out the rock at Rohri as offering a site for the headworks. Hitherto the overflow of the Indus, in floods, had formed the Nara supply. In 1826 Sir A. Burnes mentions that the Nara, which in its lower course is called the Puraun, was filled by a flood which cut through the Allah bund, and reached Lakapat. In 1843 Sir W. Baker saw marks of a flood that rose 18 feet, and in 1843 there were only 4 feet in the same place.

The cut from the Indus at Rohri to the Nara is 11 miles long, and the Nara is 20 feet below the river. Sir Bartle Frere strongly recommended the cut being made, and work was commenced in 1853; bunds were thrown across the channel at intervals, to lead off the water for irrigation. In 1854 the cut was in full progress, beginning just above Rohri; it was 16 feet deep, 206 feet wide, with a berm, 15 feet wide on each side. The excavated earth was distributed in two terraces on either bank, forming admirable garden ground. The Rohri cut or supply-channel was completed and opened on the 9th of May 1859. Bunds were also constructed across the Nara channel to prevent the escape of water into the large dunds among the sandhills.

Two canals branching from the Eastern Nara have also been constructed. The first, called the Mitrow canal, was commenced in March 1859. It was to be filled by a branch from the Nara, and in 1866 there were 190 miles open; these irrigate 156,803 acres. The second, called the Thar canal, is another branch from the Nara, intended to water lands at the edge of the desert. It was commenced in 1864, and is now completed; it irrigates about 38,000 acres; 50 masonry heads for minor channels were constructed during 1871–72.

Fuleli Canal.

The Fuleli canal is the main feeder for irrigation channels from Haidarabad southward and eastward. Originally it was a natural branch of the Indus, joining it again 16 miles below Haidarabad. This junction was closed by a dam, in the time of the Amirs, and the water was sent to feed the Gaja, Guni, and other canals to the south. The chief portion thus fell into the Guni, after a course of 40 miles, the average width being 350 feet. The improvement of the Fuleli was commenced in 1856. Two channels of supply were cut from the Indus, and the effect on the water-supply was very satisfactory. One of the most interesting services on which Sir William Baker was employed in Sind, was a survey and levels along the Guni to its junction with the Puraun (the continuation of the Eastern Nara) and thence to the Allah bund, which he surveyed and levelled. The Amirs of Sind, after an unsuccessful invasion of Kach, cut off the supply from the Fuleli and Guni, which had fertilized one of its provinces. After our occupation of Sind, the Government of Kach requested Sir Charles Napier to cut the bunds and let the water flow again. Sir Charles sent Baker to do this, who took the precaution to take levels first, and found that, owing to certain depressions and elevations caused by earthquakes, the cutting of the bunds would not restore the water to Kach, but, on the contrary, would let salt water flow back into Sind.

The great administrative question, with reference to the Sind canals, has always been the system by which they were annually cleared of silt, an operation which is absolutely necessary. The old custom was for the Government to pay for the clearance of the large canals, and for the people to keep up the minor channels. As in the case of the Punjab inundation canals, the Sind canal clearances were effected by "cher," or statute labour. Every cultivator was forced to furnish a quota of labourers in proportion to the extent of his cultivation. The silt is sometimes removed in baskets, and sometimes by a board drawn by oxen, like a gigantic hoe, trailed along the ground. But usually the only implement is a hoe, with a long blade and short handle. The labourer fills the blade by striking it into the soft soil, and by a jerk throws a shovelful upwards and behind. One man stands behind another and the soil is thus passed on. The canal-digging lasts from December to April. In 1856 statute labour was abolished; the annual work of clearance became consequently very expensive, and insufficient funds were allowed for it.

Sakhar and Shahadadpur Canal.

One perennial canal has been undertaken, from the rocky banks of the Indus above Sakhar to Shahadadpur, a distance of 63 miles. The line crosses the old Sind canal, where there is a regulating bridge of seven arches, each 10 feet span; the water is regulated by horizontal sleepers. The scheme for this canal was approved at the end of 1861, and commenced that same year; it was opened in 1870.

General Strachey, in 1867, recorded an opinion that the remedy for the inconveniences which were caused to cultivators by the uncertain water-supply of inundation canals, never under proper control, was the substitution of perennial for inundation canals. He proposed to take two perennial canals from the Indus at Sakhar and Rohri to Sihwan on the west, and to Fuleli on the east side, crossing all the present canals, and using them as distributing channels. These proposals have never been carried out. It is much to be regretted that it is so.

CHAPTER V.

BENGAL IRRIGATION WORKS.

Rainfall.—Prejudice against Irrigation.—Orissa Canals.—Midnapore Canals.—Tidal Canal.—Sone Canals.—Sarun and Hoogly Schemes.—Proposed Extensions.

THE most modern of all the large irrigation systems of India, excepting the Sirhind canals in the Punjab, are the irrigation works in the province of Bengal. The statement on p. 64 gives statistics concerning them.

The large rainfall in this province* as compared with that of other irrigated provinces, and the existence in some parts, notably in Behar, where the Sone canals are, of a well-matured system of irrigation from wells, "ahrahs" (surface-tanks), and from small "pynes" or inundation canals, has told heavily against the spread and success of irrigation works. In many parts of Bengal proper, that is in Eastern Bengal, there are no wells at all and there is no need for them. The rainfall is so large and so certain that a failure of the crops has been unknown. In this part all water for drinking purposes is kept in tanks which

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* See statement, page 10.

—	Source of Supply.	Completed up to 1878.			Approximate Annual Rainfall.	Average Area irrigation during last five years.	Area actually irrigated in 1877–78.	Actual Cost of Works to 1877–78 without Interest.	Area commanded by the Canals.	Population per square Mile in 1872.	Kind of Canal.
		Miles of Main and Branch Canals.	Distributaries.	Miles of these which are available.							
BENGAL.											
Canals in Operation.						Acres.	Acres.		Acres.		
Orissa Canals	Mahanuddi	225	642	147	51·95	36,463	98,495	1,778,090	180,000	385	Perennial.
Midnapore Canals	Cossye	77	265	77	57·16	43,472	19,819	705,177	50,000	500	„
Tidal Canal (Navigation only).	Hoogly	29		29				178,390	Nil		„
Sone Canal	Sone	331	816	183	41·65	Not open five years	241,990	1,908,504	1,100,000	516	„
								4,570,162	1,330,000		
Canals not in Operation.											
Tirhoot Project	Gunduck							53,490			
Hoogly Canal	Hoogly							14,295			
Damoodah Canal	Damoodah							15,950			
							Total -	83,736			

are excavated below the surface level. The tanks in Behar are made by low banks thrown across the smaller drainages. In Orissa the rainfall, though not so certain as in Eastern Bengal, is generally amply sufficient for the rice-crop, which is almost the only crop which is grown there; but an occasional total failure of the rains, which seems to occur every hundred years or so, brings, as it did in the famine year of 1866, total destruction to the crops, and ruin and death to the people. The irrigation in Orissa has spread more slowly than in Behar, chiefly on account of the greater amount and greater certainty of the rainfall, but the greater advance made by the Sone works in Behar is probably largely due to the very large acreage, about one-half of the total area, which is cultivated in the cold season with "rubbee" crops; this crop can never be matured without irrigation of some kind, whereas the rice-crop can be, and generally is, entirely matured by the rainfall. Although artificial irrigation increases the out-turn of rice-fields in ordinary years, and is essential to the very existence of the crop in bad years, the cultivators of Bengal, and more particularly of Orissa, have hitherto, as a body, declined to use the water to any large extent. This prejudice is, however, being slowly, but with certainty, overcome. The areas of rice-lands leased in Orissa and Midnapore are increasing largely, and although (Appendix C.) the interest and working expenses of the Bengal irrigation works exceeded, up to the end of 1877–78, the receipts by more than 1¼ millions sterling, it is yet possible that, bearing in mind the length of time which nearly all irrigation works have taken to develop, these works may yet prove remunerative. Up to the end of 1877–78 they had never paid their actual working expenses independent of interest, but the chief engineer* reports that in 1878–79 they did succeed in doing so.

The Orissa, Midnapore, and Tidal Canals.

The first suggestion which led to the construction of these canals emanated from Colonel (now Sir Arthur) Cotton,† who was deputed, in 1858, to examine the district and to report on the river Mahanuddee. His opinion was that the correct remedy for the alternate droughts and floods, which occasionally threatened the destruction of the city of Cuttack, was a system of works which would completely regulate the waters of the province. The scheme included :—

1st. Weirs across the Mahanuddee, Brahminee, and Byturnee rivers.
2nd. Irrigating channels, completed for navigation throughout the whole delta tract.
3rd. Drainage channels.
4th. Embankments to all the rivers.
5th. A high-level canal for navigation to Calcutta, which would also irrigate extensively.

The scheme included an aggregate length of 530 miles of navigable canals, which in connection with the irrigation channels were intended to irrigate 2¼ millions of acres.

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* Note by Colonel Haig, R.E., Chief Engineer Bengal Irrigation Branch, 6th March 1877.

† Accounts of the Individual Productive Works in India for the year 1876–77.

In July 1858 the Madras Irrigation and Canal Company, which had been shortly before established, expressed to the Secretary of State their readiness to carry out the works recommended by Sir A. Cotton, if interest on the capital were guaranteed by the Government. This offer was declined in 1860, and the company then offered to take up the scheme without a guarantee. A separate company—the East Indian Irrigation and Canal Company—was subsequently formed and incorporated by Act of Parliament in 1861. A contract between the Secretary of State and the company regarding the Orissa project was signed by the Governor-General in Council on the 16th of June 1862. The main provisions of this contract were, that Government was to give all land required for the works free of charge; that the company was to construct the works on designs approved by Government, and on completion of the works to distribute the water; while the Government was to collect the water-rates and pay them over, less cost of collection, to the company. Colonel (now General) Rundall was allowed by the Government to undertake the chief-engineership of the company, and under his orders a scheme similar to that of Sir Arthur Cotton was elaborated at an estimated cost of two million pounds.

The works contemplated were:—

1st. Dams and embankments to regulate and control the Mahanuddee at its debouch from the hills into the delta.

2nd. Canals for irrigation and navigation in the deltas of the Mahanuddee, Brahminee, and Byturnee.

3rd. Canals for irrigation and navigation from the Cossye, below the town of Midnapore, into the Hooghly.

4th. A high-level navigable canal from the Mahanuddee to the Midnapore canals, which would also supply irrigation to some extent.

5th. A second navigable line parallel to and near the coast connecting the high-level with the Roopnarain river near its junction with the Hooghly.

6th. A navigable canal about 135 miles in length, from a point 36 miles above Sumbhulpoor along the river Mahanuddee, to give permanent navigable communication from the country above Sumbhulpoor to the seaboard.

7th. Reservoirs on the feeders of the Mahanuddee, with the view of regulating the floods.

This scheme would have secured navigable communication between Ganjam and Calcutta, in addition to connecting Cuttack with the harbour at False Point.

The directors of the company sanctioned only a portion of this scheme. The portion sanctioned was estimated to cost six hundred and ninety-five thousand eight hundred and forty-eight pounds, including the Midnapore works and the tidal canal, and to irrigate 505,500 acres. It was assumed that 31 per cent. net profit would be obtained.

The works were commenced in November 1863, and water was available for irrigation at the end of 1865. The irrigation developed very slowly, and at the end of 1866–67 only 6,675 acres were actually irrigated, or only about 9 per cent. of the area for which water was available; in the following season only about 7 per cent. of the irrigable area was actually irrigated.

This position of affairs was far from satisfactory. As it soon became necessary to advance funds to the company to aid in carrying on the project, the Government of India suggested to the Secretary of State that the works should be purchased from the company and completed by Government agency. This, after some delay in negotiations, was effected, and on the 30th of November 1868 a formal deed was signed, in which the company agreed to surrender the works to Government on payment of one million forty thousand and fifty pounds. In addition to this, the repayment of certain advances made in India was not demanded, and some interest charges were also made, so that the total cost to Government of the works thus handed over amounted to one million one hundred and seventy-two thousand eight hundred and fifty-six pounds.

On the transfer of the work the scheme was again revised and re-estimated. The irrigable area was estimated at 1,607,000 acres, and the cost at two millions seven hundred and seventy-one thousand three hundred and ninety-seven pounds, on which a net annual return of 16 per cent. was expected.

The channels on which work had been commenced at the time of the transfer were—

In Orissa	238½	miles in length.
On the Tidal Canal	27	do.
In Midnapore	54	do.

As the continuity of the original scheme was broken by the high-level canal and the coast navigable lines not being completed, it was subsequently divided into the three sections mentioned above, which were, after the transfer, worked as separate projects.

Orissa Canals.

These canals were originally intended to irrigate 1,147,000 acres, distributed as follows:—

	Acres.
Pooree District	250,000
Cuttack "	644,000
Balasore "	253,000
Total	1,147,000

But the original proposals were so pared and cut down that the system of canals became only a small fraction of the original scheme. The area which it is now intended to irrigate is in the Cuttack district only, and amounts to only 183,000 acres, the estimated cost of which is two million five hundred and thirty-one thousand eight hundred and twenty pounds, including all book charges.

The system comprises the following works:—

	Miles.
Kendrapara Canal	55
Navigable branch of Kendrapara Canal towards Chandballee	$15\frac{1}{2}$
Pattamoondee branch	48
Taldunda Canal	27
Matchgong Canal	19
High-level Canal from Cuttack to Bhuddruck on the Salundee	$63\frac{3}{8}$

Of these, the Kendrapara and its branch towards Chandballee, the Taldunda, and the High-level, aggregating $160\frac{7}{8}$ miles in length, are navigable. The area protected from inundation is estimated at 249,000 acres.

The Mahanuddee, from which the Orissa canals draw their supply, bifurcates shortly after leaving the hills, the right branch taking the name of the Katjooree, and the left branch retaining the name of the Mahanuddee. Immediately opposite Cuttack, about three miles below the bifurcation, the Mahanuddee throws off a small branch on its left bank, called the Biropa. Cuttack is the head of the delta, and it is at this point that the headworks of the canals are situated. These headworks are rather complicated,* from the necessity which existed of regulating the discharge of the Mahanuddee down the two main branches.

There are three distinct weirs. One, across the

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* Lectures by General F. H. Rundall, C.S.I., R.E., delivered at Chatham 1875.

Katjooree at the point were the river bifurcates, is 1,200 yards long, and 12 feet high above the bed of the river. 18 feet of water flows over the crest of this weir in high flood. The second weir is across the Mahanuddee itself, opposite Cuttack; it is 1¼ miles long and 12 feet high above the bed of the river. The river rises 21 feet. The third weir is across the Biropa; it is 660 yards long and 9 feet above the bed of the river. The first weir is simply a regulating one, but is fitted with a small set of sluices for the purpose of supplying water to the city of Cuttack. The Taldunda canal, 27 miles in length, takes off from above the second or Mahanuddee weir, on the right bank of the river; this canal runs along the bank of the Mahanuddee and rejoins it at Taldunda. From the pool above the Biropa weir canals take off on both banks; that on the right bank, the Kendrapara canal, 55 miles in length, follows the left bank of the Mahanuddee for some distance; it then runs along the high bank of another branch of the river. That on the left bank, the High-level canal, leaves the river at once, and flowing close by the foot of the hills, falls into the Brahminee river, after a course of 63½ miles. The Matchgong navigable canal is a branch of the Taldunda; the Pattamoondee and Chandballee navigable canals are branches from the Kendrapara canal.

The main canals, having been constructed in the first instance by the East India Irrigation Company to irrigate an area of about 1,147,000 acres, are part of a much more extensive scheme than has been actually carried out; the cost of the works is, therefore, much greater than it would have been had they been designed only for the small area now irrigable. The Government persistently refuse to allow any extension of distributaries, which would bring a much larger area under command, until there are signs of increased demands for water on the part of the cultivators.

But the system is capable of great extension should the prospects of irrigation brighten in Orissa,* for the canals actually constructed command an area between two and three times that now irrigable. No distributaries have been provided for some of them in the sanctioned estimates. Another 464,000 acres might be irrigated in the Cuttack district by one or two short extensions of existing canals, and the construction of distributaries; 150,000 acres more in Balasore by the extension of the present high-level canal beyond Bhuddruck, where it now terminates; and 250,000 acres more by the construction of canals in the Pooree district. The headworks for all these canals have long been finished, and there is an ample supply of water in the rivers in all seasons. Thus the present irrigable area of 183,000 acres might be increased to 736,000 acres, at an increased outlay of about one million six hundred and eight thousand four hundred pounds.

Midnapore Canal.

The second section, into which the works of the East India Irrigation Company were divided, was the

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* Note on Irrigation and Communications in Bengal, by Colonel F. T. Haig, R.E., Calcutta, 30th December 1878.

Midnapore canal. This canal draws its supply from the river Cossye. The basin of this river* is so small that the supply of water in the canal practically varies with the rainfall of the district commanded by the canal itself. The works were commenced by the company in ignorance of the real supply available from the river. Distributaries have actually been constructed for an area of 140,000 acres, and in seasons of average rainfall there is little doubt that the supply would be sufficient to irrigate that area; but in years of extreme drought, as in 1873, the quantity of water in the river would only be sufficient for 40,000 or, at most, 50,000 acres. Thus, in Midnapore, irrigation is little wanted in years of heavy rainfall when a large supply is available; and in years of extreme drought, when it is of the utmost value, the water-supply fails.

The Midnapore canal is divided into four lengths. The first length takes off the Cossye river above the weir which is built across it at Midnapore; this length falls into the river again at Panchkoorah, in the twenty-fifth mile, where a second weir is built across the river. The canal crosses the Cossye at this point, and the second length takes off from the other bank. At the thirty-sixth mile the canal tails into the Roopnarain river. Five miles from the tail-lock the canal leaves the Roopnarain again on the opposite bank. The third length, commencing from this point, takes the canal by a cut 4 miles long to the Damoodah river. The fourth length connects the Damoodah with the Hooghly at Oolooberia. From Oolooberia to Calcutta by the Hooghly river is 17 miles.

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* Note by Colonel F. T. Haig, R.E., Chief Engineer Bengal Irrigation Branch, on the Canal Revenues of Bengal, 6th March 1877.

The Midnapore canal thus forms a navigable connection between Midnapore and Calcutta. The canal crosses three rivers in its course. Of these, the Roopnarain and the Damoodah are occasionally difficult to navigate.

Tidal Canal.

This work is one for navigation only; it is in two lengths, one of 11 miles from the Hooghly to the Huldee, the other 18 miles from the Huldee to the Russoolpore river.

The Sone Canals.

The history of these canals is, in some respects, similar to the history of those in Orissa. The works were in the first instance taken up by the East Indian Irrigation Company and given over by them to the Government; but hardly any actual work was done by the company, who only expended fourteen thousand pounds on the scheme.

The country irrigable by this system of canals lies to the south of the Ganges, near the confluence of that river and the Sone; it comprises portions of the district of Shahabad, on the west of the Sone, and Gya and Patna on the east. The scheme was originally proposed by Lieutenant (now Major-General) C. H.

Dickens* to the Government of Bengal in January 1853. His first idea was to irrigate the Shahabad district from storage reservoirs in the hills lying to the south of Shahabad, but it was soon found that the supply of water in the Sone river was amply sufficient to irrigate an area of at least 800,000 acres ; consequently a scheme, to utilise the waters of the river, was projected by Colonel Dickens, who submitted the details to the Government in 1861. This scheme comprised 484¼ miles of irrigating canals which were also navigable, 145 miles of canals for navigation only, and 217¼ miles of main canals not available for navigation. Of these, 347¾ miles were on the east of the Sone in the Patna and Gya districts, the remainder (499 miles) being in the district of Shahabad. These works were estimated to cost two million six hundred and eighty-eight thousand one hundred and twenty pounds, on which a net profit of 8¾ per cent. was predicted.

In September 1861 the project was forwarded to the Secretary of State. In May 1862 the Secretary of State intimated his approval of the measure, and an offer was made by the East India Irrigation Company to undertake the works.

After some correspondence regarding the conditions of the agreement, and the scope of the project, a general sketch of the works contemplated, as proposed by Sir A. Cotton and Colonel Rundall, was forwarded on the

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* Accounts of Individual Productive Public Works in India for the year 1876–77.

6th of April 1864, for the approval of the Government of India. The main features of this project were as follows :—

1st. A weir and headwork on the Sone about 25 miles north of Rhotas, whence canals were to be led off to the west and east.

2nd. A Main Western canal to pass near Sasseram and Chunar, and thence in a direction parallel with the Ganges river to Allahabad, where an aqueduct across the Jumna would connect it with the Ganges canal system; also branches from this canal for the irrigation of the tract between it and the Ganges, some of which would also be navigable.

3rd. A Main Eastern canal to pass near Gya to Monghyr, thence along the Ganges to Rajmahal and the Bhagiruttee, which was to be crossed near its head; thence turning southward and passing near Kishnaghur, it was to terminate in the Hooghly at or near Calcutta. Connection with a proposed canal system in Oudh was to be effected by an aqueduct across the Ganges at Monghyr or Colgong. Irrigation was provided for the tract between the Sone and Monghyr by branches to the northward, and on the line from Rajmahal to Calcutta it was also considered that a considerable area would be irrigated.

4th. Reservoirs in the hills south of Rajmahal were also contemplated to supplement the water available from the Sone.

The Tonse, the Kurrumnassa, and other rivers crossing the canals would, it was expected, also aid in the supply of water.

This scheme was considered by Government to be far too extensive; a lengthy correspondence ensued, which terminated in the acceptance by the company of the condition originally prescribed by Government that the scope of the project should not exceed the limits of Colonel Dickens' scheme, and an agreement was signed on the 10th of August 1864, generally similar in its provisions to that executed for Orissa, in which the limits of the project to be carried out were stated to be Chunar on the west and Patna on the east.

As the company failed to raise the necessary capital, under the conditions of the contract, they applied to Government in February 1867 for a guarantee of 5 per cent. on the outlay. This was refused, and the negotiations with the company finally terminated in their transferring the undertaking to the Government, with all plans and information collected by their officers. The sum expended by them (fourteen thousand pounds) in preliminary operations was reimbursed. The deed effecting the transfer bears date the 21st of December 1868.

The scheme, as undertaken by the Government in 1869 consisted of—

1st. A weir and headworks, same as proposed in 1864.

2nd. Two main canals, one on the western side of the river to join the Ganges at Chunar, and one on the eastern side to join the Ganges at Barrh.

3rd. On the western side, two branch navigable canals, one to Arrah and the other to Buxar; on the eastern side, navigable branches to Patna and Barrh.

4th. Distributaries aggregating 928 miles in length.

This scheme was estimated to cost three million seven hundred and seventy-five thousand pounds; the area commanded was 2,611,000 acres, of which 1,200,000 were on the western side, and 1,411,000 on the eastern. The navigable canals aggregated 535 miles, as follows:—

	Miles.
Main Western Canal	125
Arrah Branch	70
Buxar Branch	50
Main Eastern Canal	170
Patna Branch	84
Barrh Branch	36
Total	535

It was estimated that one-half of the total area commanded, that is 1,305,500 acres, would be rice-land, and it was assumed that one cubic foot of water per second would irrigate 133 acres of rice; hence, the Eastern Main canal was designed to carry 5,304 cubic feet per second, and the Western Main canal 4,511 cubic feet per second. On the assumption that 220 acres of cold-weather crop could be irrigated with 1 cubic foot of water per second, it was estimated that out of the 1,305,500 acres of cold-weather crop which were irrigable, 880,000 acres could be irrigated by the cold-weather discharge of the Sone which is about 4,000 cubic feet per second. It has since been proved that 1 cubic foot of water per second cannot be expected to irrigate more than 80 acres of rice-land and 180 acres of cold-weather crop.

The scheme, commenced in 1869, was estimated to give a net profit of 12½ per cent. on the outlay. This scheme was approved by the Government of India in March 1871, and confirmed by the Secretary of State in the following July. The works were actually and energetically commenced in 1869.

It was decided in 1871 to restrict the scope of the canal; for it was found that the supply of water in the river was not sufficient to irrigate more than 480,000 acres of cold-weather crop, and as it was considered advisable and economical that the area of the summer and winter crops which were irrigated should be about equal. For other reasons also it was decided to limit the canals within the area bounded on the east by the Poonpoon river, and on the west by the Koodra nullah. This system is now nearly completed, and about two-thirds of the total estimate has been expended.

The weir across the Sone, which is the headwork of this system of canals, is situated at Dehree about 25 miles below the point where the river leaves the Kymore range of hills; it is the longest weir in one unbroken length of masonry which has ever been built. It is 2⅓ miles in length and 8 feet high; the river in flood rises 8½ feet over the crest of the weir and discharges about 750,000* cubic feet per second. General Dickens estimated the flood discharge at 1,026,000† cubic feet per second, but his estimate was too great. The catchment basin of the Sone is about 23,000 square miles. The river runs for 325 miles through the hilly parts of Central India, until it reaches the plains at Rhotas; from that place it has a course of about 100 miles through an almost deltaic country, which is the area commanded by the Sone canals. For about 40 miles below the weir the floods of the river do not overtop the banks, but below that considerable spills take place and flood the district. Up to about the point where these spills commence the canals follow either bank of the river pretty closely, but at that point they leave the bank and follow high ridges of the country down to the Ganges.

The following table gives the lengths of main navigable canals :—

	Miles.
Main Western Canal	21½
Arrah Branch	65
Buxar Branch	45
Main Eastern Canal	7
Patna Branch	79
Total	217½

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* Report by Major J. G. Forbes, R.E., on the flood in the river Sone on the 7th July 1876.

† Report on the Sone Canal Project by Mr. H. C. Levinge, dated the 31st December 1870.

The Main Western canal takes off from above the weir on the west bank of the river; it is navigable without locks to Sasseram. This canal crosses the Kao river by a large syphon aqueduct in the ninth mile, it also crosses two smaller drainages, one in the seventeenth and one in the twenty-first mile.

The Arrah canal leaves the Main Western at the fifth milestone. It follows the bank of the Sone river for the first 33 miles; it then leaves the bank of the Sone, passes close by the large town of Arrah, and drops into the Gungee nullah which communicates with the Ganges. There are thirteen locks on the canal, with an aggregate fall of 161 feet. It was hoped that the Gungee nullah could have been made navigable throughout the whole year, but it has been found impossible to keep the nullah clear of silt at any reasonable cost. The Arrah canal is therefore in navigable connection with the Ganges for only about six months in the year.

The Buxar canal leaves the Main Western canal at the twelfth milestone, it has almost a straight course from that point to the Ganges at Buxar. There are twelve locks on the canal with an aggregate fall of 153¾ feet; at the twenty-ninth mile the canal is carried across the Thora nullah by an aqueduct having four arches at 30 feet span. The canal falls into the Ganges a little above the fort at Buxar where the bank of the river affords excellent foundation, and where there is no fear that any banks or shoals will interfere with navigation.

The Main Eastern canal takes off from above the

Sone weir on the east bank of the river. It is only 7 miles in length without any locks; it stops at the Poonpoon nullah over which, in the schemes of 1861 and 1864, it had been intended to carry it by a large aqueduct.

The Patna canal leaves the Eastern Main canal at the fourth milestone. It follows the bank of the river for 60 miles; it then leaves the river and follows a ridge which was probably at one time the bank of the Sone, until it runs into the Ganges close to Patna.

In addition to the above main canals there will be about 900 miles of distributaries connected with this system. The full summer supply to be carried by the canals is now taken to be 5,171 cubic feet per second, and a minimum of 3,500 cubic feet is reckoned upon up to the end of March. The supply during May and June falls to about 500 cubic feet per second in a very dry year. The total irrigable area is about 1,100,000 acres. The total area commanded by the canals, that is the area between the Poonpoon on the east and the Koodra on the west, is estimated to be 2,934 square miles. Assuming that 500 acres per square mile are cultivated, which in this highly cultivated and thickly populated district is probably true, the area irrigable will be about 70 per cent. of that commanded.

The scheme as sketched out above was estimated in 1875 as follows:—

	£
1. Headworks on the Sone	240,291
Western Series:	
2. Main Canal	268,439
3. Arrah Canal	510,012
4. Buxar	385,433
Eastern Series:	
5. Main Canal	34,167
6. Patna Canal	493,238
Total Works	1,930,580
Maintenance previous to admission of water	35,901
Establishment	495,523
Tools and plant	248,357
Total Cash Outlay	2,710,361

	£	
Indirect charges:		
Interest on outlay during construction	296,723	
Provision for leave and pension allowances	123,881	
Capitalization of abatement of land revenue on land occupied	16,080	
		436,684
Grand total		£ 3,147,045

This estimate included the cost of a field survey of the whole area irrigable.

The profits of the system of canals as they now are was estimated in 1875 as follows:—

	Rupees.
413,680 acres of summer crop at Rs. 3 an acre	12,41,040
630,000 acres winter crop at Rs. 3 per acre	18,90,000
327,000 acres single waterings at Ans. 8 per acre	1,63,500
Miscellaneous income	20,000
Navigation tolls	1,08,750
Gross Income	34,23,290
Deduct:	
Maintenance on 1,043,680 acres at Ans. 12 per acre	7,82,760
Net Income	26,40,530

Thus giving a return of 8·3 per cent. on the outlay.

These canals have been barely opened five years, and it would be premature as yet, in the undeveloped state of the works, to speculate as to whether this profit of 8·3 per cent. is likely to be realised. Up to 1877–78 these canals did not pay their working expenses, but they did do so in the following year. In a forecast prepared by Colonel (now General) F. T. Haig, R.E., the late Chief Engineer of Bengal, it is estimated that the Sone canals may be reasonably expected to pay both the interest on the capital expended and their working expenses, in the year 1887, and that after that a profit over and above the 4½ per cent. interest on capital may be expected.

Sarun and Hooghly Schemes.

These two small irrigation schemes, which are estimated to cost only sixty thousand and fifty thousand pounds each respectively, have only lately been commenced. The Sarun scheme will, by means of some short cuts from the Gunduck river, throw a small quantity of water into some old channels which intersect the district. The distribution of the water from these channels will be undertaken by the planters and landholders who have guaranteed the interest on the capital. The area commanded by the Sarun scheme will be about 100,000 acres only; that commanded by the Hooghly scheme is 70,000 acres.

The irrigation works in Bengal* at present sanctioned command the following areas:

	Acres.
Orissa Canals . . .	183,000
Midnapore Canals . . .	50,000
Sone Canals	1,100,000
Sarun Scheme . . .	100,000
Hooghly Scheme . . .	70,000
	1,503,000

It may almost be said that these works are already constructed, for they are nearly complete, with the exception of minor channels, which must, in any case, take years to complete.

In the paper* quoted in the foot-note Colonel Haig stated that,

	Acres.
The total area of Bengal, including Behar and Orissa, which is under food-crops, is about .	48,634,000
In the Eastern Districts of Bengal there is an area which is always secure against drought of	13,634,000
So that the area which is liable to drought is about	35,000,000

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* Note on Irrigation and Communications in Bengal, by Colonel F. T. Haig, R.E. Calcutta, 30th December 1878.

Colonel Haig then discussed how much of this area it would be advisable to protect by extensions of the present works or by the construction of new ones; he arrived at the conclusion that if 3,000,000 acres were irrigable from canals in the province, in addition to the area already protected by wells and streams, that Bengal could produce sufficient food to protect herself from fear of any repetition of the scarcity of 1873–74. Colonel Haig proposed to obtain this irrigable area by making the extensions of the Orissa works which have been mentioned as possible in the above account of those works, by a trifling extension of the Main Western canal of the Sone system, and by the construction of a large system of canals in the districts of Tirhoot, Sarun, and Chumparun in North Behar. This last scheme is one which was surveyed and worked out by Major (now Colonel) Jeffreys, R.E., in 1870.

These proposed extensions of irrigation in Bengal would then command the following areas:—

	Acres.
Orissa Canals . . .	736,000
Midnapore Canals . . .	50,000
Sone Canals	1,230,000
Sarun Scheme . . .	100,000
Hooghly Scheme . . .	70,000
North Behar Scheme . . .	1,100,000
Total . . .	3,286,000

In addition to these, several navigable canals were recommended to facilitate intercommunication.

CHAPTER VI.

THE IRRIGATION WORKS OF THE NORTH-WEST PROVINCES.

The Jumna and Ganges.—Rainfall.—Eastern Jumna Canal.—Ganges Canal.—Agra Canal.—Dun Canals.—Bijnor Canals.—Rohilkhund Canals.—Bundelkhund Canals.—Lower Ganges Canal.—Eastern Ganges Canal.

THE North-West Provinces (including Oudh) have an area of about 55,000 square miles*; of these 25,500 square miles may be said to be protected by works of irrigation. 20,000 square miles of the Ganges-Jumna Doab are protected by the Eastern Jumna and Ganges canals, 3,000 square miles by the Agra canal, and 2,500 square miles by the other works. These areas are not, of course, entirely and completely irrigated, but they are protected from the fear of famine by the irrigation works which command a portion of the areas named.

The large irrigation works of this province draw their supply from the two great rivers, the Jumna and the Ganges, which flow through it. These rivers, after traversing the Himalayas along a course of 110 and 165 miles respectively, open out upon the valley of Deyrah.* At the points where they leave the great Himalayan chain, they are separated (measuring from the Jumna at Kuttur Puttur to the Ganges at Rikekhes) by a distance of 38 miles; the Ganges forming the eastern and the Jumna the western boundary of the valley. In their onward progress these two great rivers force a passage through the Sewaliks, a range of tertiary hills that separate the valley from the plains of India. The debouch of the Ganges upon these plains takes place at the town of Hurdwar, that of the Jumna is just below the valley of Kulesur on the right, and the Kharra head of an old branch on the left, of the river.

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* Review of the Progress of Irrigation Schemes by Colonel F. H. Rundall, R.E., page 436 of the Report of the Select Committee of India Public Works, 1878.

Down to Hurdwar the Ganges, after leaving the main chain of the Himalayas, leads off the drainage of the eastern slope of the Deyra valley by the channels of two streams, the Song and Soozwa; the drainage of the western slopes being carried through various channels of a subordinate character. The Jumna river, in its passage from the Himalayas, drains a considerable area of the western slope of the Deyra valley; this drainage is carried to the Jumna by the Asun river. The Jumna drains also, on its right bank, very extensive tracts of mountain and valley by means of the Tonse and Girri. These two streams rise in the Sirmoor country. They are perennial in their supply, bringing down, in the rains, large volumes of water, and in the dry months also they maintain a considerable discharge.

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* A Disquisition on the Heads of the Ganges and Jumna Canals, by Sir Proby T. Cautley, K.C.B.

At the town of Hurdwar, and at the Kharra head where the Ganges and Jumna leave the mountains and issue into the plains, the dry-weather discharge of these rivers may be estimated at about 8,000 and 4,000 cubic feet per second respectively. The slope of the beds of the rivers down to these points is very great. The beds are largely composed of rocks and boulders. In the latter part of their course, after having left the great mountains, the rivers appear in lengths of open stream and heavy rapid alternately. Some of these rapids are of the most formidable character, one on the Jumna, in its passage through the Sewaliks, called the Dhobra rapid, flows with great force upon a huge and lofty cliff of sandstone on the left of the river, and has been the grave of many a raft and many a raftsman. During the rainy months, these alternate reaches and rapids are converted into a continuous mass of rolling water, the rapids being engulfed, and the whole river having the appearance of an overwhelming cataract. The water during the dry months, and when undisturbed by floods, is as clear as crystal, and the boulder-bed over which it passes is visible at great depths. The boulders and shingles gradually disappear from the beds of the rivers at a point from 12 to 16 miles below their debouch from the Sewaliks. From this point the rivers proceed onwards, through a trough or k'hadir, on a much reduced slope over a bed of coarse quartz or sand mingled with mica, the latter ingredient being less abundant as the river advances.

The Ganges and Jumna, where the canals issue from them, are perennial in their supply, the Ganges having drained a vast tract of elevated mountain country by its two great branches (Bhageretti and Aluknunda), both of which have their origin in the snow. The Jumna also drains a considerable though smaller area. The fountain-head of the Ganges springs at the foot of that gorgeous mass of perpetual snow which forms so remarkable an object from the plains, well known as the Gungootri mountain. The Jumna rises from an equally well known and conspicuous mass of snow—the Jumnootri mountain, which is perhaps even more remarkable.

The rainfall of the Upper Gangetic plains is given by the Meteorological Department as 38 inches, but the rainfall of the Ganges-Jumna Doab is only about 30 inches. The chief crop grown is the cold-weather or rubbee crop. The summer or khareef crop is of less importance, and bears a much smaller proportion to the cultivated area than in Bengal, Orissa, and Madras, where the khareef or rice-crop is the one on which the people chiefly rely.

The statement found on the next page gives statistics concerning the irrigation works of the North-West Provinces.

Works.	Source of Supply.	Completed up to 1878.			Approximate annual Rainfall.	Average Area irrigated by the Canals during the last five years.	Area actually irrigated in 1877–78.	Actual Cost of Works to 1877–78 without Interest.	Population per square Mile in 1872.	Kind of Canal.
		Miles of Main and Branch Canal.	Miles of Distributaries.	Total.						
NORTH-WEST PROVINCES.										
Works in Operation.						Acres.	Acres.	£		
Eastern Jumna	Jumna	130	618	748	32·2	188,648	206,732	261,235	452	Perennial.
Ganges Canal	Ganges	593	3.417	4,010	28·1	906,036	1,045,013	3,055,015	489	„
Agra Canal	Jumna	140	313	453	28·8	63,950	163,634	804,479	563	„
Dun Canals	From small streams and lakes		66	66	71·3	13,202	12,360	62,452	·114	„
Bijnor Canals			32	32	37·3	3,072	2,123	6,996	387	„
Rohilkhund Canals			292	292	40·8	52,475	30,076	148,207	353	„
Bundelkhund Canals					31·2	1,702	1,491	8,262	217	Tank.
						1,229,085	1,461,429	4,346,646		
Works not in Operation.										
Lower Ganges Canal	Ganges							1,267,125		In progress.
Eastern Ganges Canal	Ganges							27,052		Surveyed only.
Bundelkhund New Canals.	Desan & Ken.							32,574		„
Agra Irrigation Works	Jumna.							22,197		Abandoned.
								1,348,948		

Eastern Jumna Canals.

The Eastern Jumna canals are said to have been first projected by Shah Jehan,[*] between 1628 and 1659, and had been partially restored in 1764 by a chief named Zabitha Khan. The works were taken in hand by the British Government in 1823, when Captain Robert Smith commenced their restorations.[†] These canals irrigate the districts of Saharunpoor, Mozuffurnugger and Meerut. The system consists of 130 miles of canal and 618 of distributaries watering a tract about 120 miles long and 15 broad. Sir Proby Cautley joined Colonel Smith in 1825 in the execution of the works, and the canals were opened in 1830 under his superintendence. A portion of the canal was remodelled in 1854, in the part where it crosses from the Saharanpur into the Mozuffurnugger district. A new line was made crossing the Shambi-nulla, an affluent of the Kindun, in several places; three cuts were also made for the escape of water. These effected the Katha, a tributary of the Jumna, and caused swamps to form in the valley of that stream. In 1872 Captain Harrison was deputed to report upon a remedy for these evils, which very injuriously affected the land and the health of its inhabitants. He projected a scheme to drain off the water which swamped a wide tract of country.

The head of the canal is situated near Raipur, on the Jumna, a few miles below the point where the Jumna leaves the Sewalic hills. The head of the

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[*] "Moral and Material Progress of India, 1872–73," p. 62.

[†] *Ibid.*, p. 63.

Eastern Jumna canal is about 3 miles below that of the Western Jumna canal, which irrigates the country lying to the west of the Jumna in the Punjab.

The country at the foot of the Sewalic range, at which point the head of these canals is situated, is crossed by many mountain torrents, which are intersected by these canals under circumstances of remarkable difficulty. The canal after passing down* the shingly bed of the Boodhee Jumna for the short distance of 4 miles, enters on deep cutting, and takes a south-easterly direction, commencing at the village of Nyashuhur; from this point it plunges at once into all the difficulties peculiar to a line crossing mountain drainage at right angles to its course. The Raipoor, Jatonwala, Nogong, and Muskurra, four mountain torrents of greater or less dimensions, are passed within a distance of 10 miles from the Nyashuhur deep cutting. The Muskurra and the Nogong are torrents of considerable magnitude, and are provided with masonry dams for the passage of floods during rains. After passing the Muskurra, the Eastern Jumna channel continues on the high land of the country, running nearly parallel with the Jumna at a distance varying from 4 to 8 miles from the river. The canal passes near Saharunpore, and finally returns to the Jumna at Delhi.

The mountain torrents with which the Eastern Jumna canal has had to contend have now been entirely and satisfactorily controlled. The canal runs for some distance parallel to the range of mountains, the land having a fall to the eastward; the torrents, which have their course generally at right angles to the line of the canal, have been to some extent diverted from their original courses, a portion of their waters being turned to the eastward above the line of canal. By this means the quantity of water which has to be discharged across the canal has been reduced. The result of these arrangements* has been to reduce the Muskurra at its point of contact with the masonry dam at Kulsea to a comparatively inconsiderable volume. The Jatonwala drainage has on the same principle been turned into the Nogong river. At times, the violence of a Nogong flood has been relieved by allowing a portion of its volume to pass down the canal channel towards the Muskurra.

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* "The Ganges Canal," by Sir Proby Cautley, chap. i. part ii.

The canal is one of the most remunerative in India. It paid nearly 23 per cent. in 1878 on the capital expended upon it by the British Government. This capital, however, does not represent the full value of the works, although great alterations, re-alignments and improvements have been made, for the value of the old native works is not represented in the capital account. The cost of the works to the end of 1877–78 was two hundred and sixty-one thousand two hundred and thirty-five pounds.

Ganges Canal.

The earliest canal of which any record is obtainable, in the district now commanded by the Ganges canal, is that of Muhummud Aboo Khan, near Meerut; it is now only to be traced by its remains. It consisted* of a cut made from the West Kalli Nuddi, near the village of Rampoor, to the head of a small tributary of the East Kalli Nuddi, called the Khodara nulla, which rises near the village of Deorla. The length of this cut did not exceed 12½ miles, and its dimensions, judging from the existing hollow, could not have exceeded 15 feet in width. The water after reaching Deorla must have passed down the Kodara nulla to the town of Meerut, in the neighbourhood of which there are many groves and gardens, and it is supposed that it was for the purpose of supplying water to these that the canal was originally projected. There is no tradition, however, of its existence as a running stream, although there is no reason to doubt that for a season, at least, it was so. The canal was evidently one of those which, from the circumstances affecting its supply, and from the total absence of all masonry works, could not have been classed under the head of a permanent work for irrigation. The West Kalli Nuddi at the village of Rampoor, although a perennial stream, is one of those lines of drainage which, during the periodical rains, is subject to very great floods. The river meanders through a valley of considerable extent, and during the dry months is 30 feet below the level of the country, or below the level of the land over which Muhummud Aboo Khan's canal was carried. The canal was merely excavated to a few feet in depth, and water was supplied from a lake, formed by throwing an embankment across the bed of the West Kalli nuddi. The flooding of the valley, by this retention or damming up of its waters, must have done extraordinary damage to the properties within its limits; the amount of labour and money expended on an embankment, of proportions sufficient to gain the engineer's object, must have been very great; and the necessity for an annual reconstruction of a work which was inevitably destroyed during the floods, and the certainty that water could only have reached the mouth of the canal during the dry months of the year, are facts which reasonably lead us to conclude that no great benefit was ever derived from it by the cultivators on the high lands in its vicinity.

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* "The Ganges Canal," by Sir Proby Cantley, chap. i. part ii.

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* "The Ganges Canal," by Sir Proby Cautley, vol. i, p. 6.

The Ganges canal* waters a considerable portion of the tract between the Ganges and Jumna rivers. The idea of drawing water from the Ganges river originated with Colonel Colvin, who, when transferring charge of the canals in Northern India to his successor Captain (afterwards Sir P. S.) Cautley, in 1836, recommended an investigation of the subject. This was carried out; but the results not being encouraging, nothing further was done until the great famine of 1837–38 again drew attention to the matter, when orders were issued by Government to re-examine the question.

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* **Accounts of the Individual Productive Works in India for the year 1876–77. Calcutta, 1879.**

The first proposals, in a practical shape, were made by Sir Proby (then Captain) Cautley in 1840, when he submitted a rough project on a small scale, which it was considered would prove remunerative. The main canal was designed both for irrigation and navigation, the irrigable area being fixed at 218,750 acres. The returns were estimated from results on the East and West Jumna canals at 10 per cent. on the outlay. This scheme was estimated to cost two hundred and fifty-nine thousand one hundred and fifteen pounds; the canal was designed to carry 1,000 cubic feet per second, the length of the main line was 255 miles, and there was a branch from it of 73 miles in length. The Governor-General considered it advisable that this scheme should be increased and extended in order to utilise the full supply available in the Ganges. This was approved by the Court of Directors in September 1841.

A committee was appointed who recommended a scheme which was estimated to cost seven hundred and twenty-two thousand six hundred and forty pounds; it contemplated a discharge of 6,750 cubic feet per second, and an irrigable area of 1,473,920 acres; the estimate was for main canals and branches only, as it was intended that all distributaries should be constructed by the landowners, as had been done on the neighbouring works of the East and West Jumna canals. Work was commenced on this project in 1842.

In February 1845 Captain Cautley submitted detailed estimates for three separate projects. In each of these the discharge at full supply was 6,750 cubic feet per second; of this quantity it was assumed that 1,000 cubic feet would be lost by evaporation, absorption, and navigation, and that the remainder would be available for irrigation. The last of these projects, which was estimated to cost nine hundred and thirty-three thousand nine hundred and seventy-four pounds, was recommended for adoption by Captain Cautley and subsequently approved by Government.

This scheme contemplated a main line of canal from Hurdwar to a point near Allygurh, whence two branches were to bifurcate, one terminating in the Ganges at Cawnpoor, the other (the Etawah branch) in the Jumna at Jar.

The above lines were to be navigable throughout, and two other branches were to be taken off above Allygurh. The proposed lengths were as follows:—

	Miles.
Main line	380
Futtehgurh Branch	160
Bulundshuhur Branch	70
Cawnpoor Branch	63
Etawah Branch	172
	845

Nine escape channels were provided from the main canal and three on the Cawnpoor branch. Compensation for land occupied by the works and provision for establishment charges were not included in any of the above estimates.

The returns were thus estimated. The duty of the water was taken at 218·75 acres per cubic foot per second of water-supply and the rate at one rupee per acre.

	£
Water-rate 5,750 × 218·75 = 1,257,812·5 acres at Rs. 1	125,781
Mill power	10,000
Navigation Tolls	6,000
Sundries	718
Gross Income	142,499
Deduct working expenses	39,044
Net Profit	103,455

or 10·34 per cent. on the expenditure of, say, one million pounds. In May 1847 the Government of India directed that the works should be vigorously pushed on, and added the following instructions :—

1st. The primary object of the canal to be irrigation, navigation to be carried out in so far as it was not inconsistent with irrigation.

2nd. The works in the Ganges valley above Roorkee to be as recommended by Captain Cautley. The precise course of the channels below Roorkee to be subsequently determined.

3rd. The proportions proposed by a medical committee, which had recommended some alterations in the designs of the canals on sanitary grounds, to be adopted. The chief of these recommendations was that the main canals were to be kept as far as possible within soil—and all irrigation to be given from distributary channels and not from the main canals.

These alterations having been incorporated in the estimates raised them to one million five hundred and sixty thousand five hundred and eighty pounds. The chief causes of the excess of this estimate over the former ones were, in addition to the alterations recommended by the medical committee, the reduction of the slope of the bed in the upper portion of the main line necessitated by the sandy nature of the subsoil, the consequent increase in the number of masonry falls, the alterations in the distribution of the water to the branches, the increase in the number of bridges, and the buildings necessary for sheltering the establishment.

Water was admitted into the canal in April 1854, and irrigation commenced in the following year.

During the next few years defects in the works gradually came to light, which it is unnecessary here to recapitulate in detail. The chief defect was excessive declivity in the bed of the main channel, which caused a velocity of current greater than the sandy soil was calculated to withstand without erosion. An investigation was accordingly ordered by the Government of India in 1864. At the close of that year—

Three detailed estimates were submitted :

1st. For rectifying defects on the existing main line and Cawnpoor branch, and remodelling the main line to enable it to carry the full supply as originally projected, viz. 6,750 cubic feet per second.

2nd. For an alternative channel, 167 miles in length, from the great aqueduct at Roorkee (18 miles from the head) to the bifurcation of the Cawnpoor and Etawah branches at the one hundred and eighty-first mile to carry a portion of the full supply. The existing channel was large enough to carry the remainder, without any material alteration.

3rd. For a separate channel, 165 miles in length, between the same points as in No. 2. This was for navigable communication only.

The lengths of the several channels of the canal at that date were as follows :—

	Miles.
Main Line	181
Futtehgurh Branch	82½
Bulundshuhur Branch	45
Koel Branch	Not commenced
Cawnpoor Branch	170
Etawah Branch	170
Total	648½

The aggregate length of distributaries constructed was 2,266 miles, and the total capital outlay to the end of the official year 1862–63 was calculated to have amounted to two million one hundred and fifty-five thousand nine hundred and ninety-seven pounds.

It was decided that the best course to follow was to rectify the defects in the existing channels to enable them to carry the full supply as originally projected. If this course were finally decided on the probable total capital outlay on the Ganges canal was estimated at three million and eighty-four thousand one hundred and ninety-two pounds. This estimate included the cost of distributaries which had been previously omitted in all estimates, but no provision was made for land compensation.

In 1863 Sir Arthur Cotton* visited the works of the Ganges canal, and reported for the information of the East India Irrigation Company on the works of the canal and the improvements which he considered necessary to make the works successful. In his report he stated that there were the greatest fundamental mistakes in the projection of the canal. These were :—

1st. That the head of the canal was placed too high up the river, above a tract which had a very great and inconvenient fall, and in which there was a very heavy drainage from the sub-Himalayas across which the canal had to be carried.

2nd. That the whole canal had been cut so as to carry the water below the level of the surface, entailing a vast unnecessary excavation, and keeping the water below the level at which it was required for irrigation.

3rd. That the whole of the masonry works were of brick, while the most suitable stone for hydraulic works was procurable in the sub-Himalayas.

4th. That the whole of the water was admitted at the head, so that some of it was conveyed 350 miles to the land it irrigated, while it might have been obtained at a sufficient level at a distance of, say, 50 or 100 miles.

5th. That there was no permanent dam across the river at the head of the canal, so as to secure the supply of water, but temporary works were thrown up after every monsoon, which were liable to be swept away at the very time when they were most wanted.

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* Memorandum by Major-General Sir Arthur Cotton upon the Ganges Canal, July 1863.

In addition to these Sir Arthur Cotton enumerated fourteen minor mistakes which he said he had detected in the canal.

Sir Arthur Cotton in his report suggested a scheme of alteration and improvement of the canal which he thought necessary to make this most important work complete and thoroughly effective both for irrigation and navigation. The chief suggestions made were:—

1st. To form a new head with a permanent weir below the confluence of the Solani, through which the main supply of the canal would be received.

2nd. To construct new weirs below this new head, and to add such additional weirs with locks as would reduce the slope of the bed to about 3 inches or 6 inches a mile.

3rd. To form a large basin at the heads of the canals as a silt-trap.

4th. To extend the canal to Allahabad and to form additional heads with permanent weirs both in the Jumna and the Ganges, 200 or 300 miles below the Solani, so as to admit additional water into the lower part of the canal.

5th. To cut cross lines of canal connecting the different branches at several points.

6th. To make distributaries and drainage channels for the extended irrigation.

Sir Arthur Cotton estimated the additional capital required to carry out his suggestions at two million seven hundred and twenty-five thousand pounds. He then thought 6½ million acres would be commanded for a total sum of five million pounds.

This report of Sir Arthur Cotton's was the commencement of a long and acrimonious discussion between him and Sir Proby Cautley on the works of the Ganges canal. Sir Proby Cautley admitted in his replies to Sir Arthur Cotton that he had made a mistake in the excessive slope which he had given to the bed of the canal, but he denied that Sir Arthur Cotton was right in condemning any other of the details of the project than this one of the slope. In 1866 a committee was convened by order of the Government "to decide upon the propriety of proceeding as previously determined with the project of 1864 for remodelling the canal, or of stopping its progress pending the preparation of a detailed project according to the views of Major-General Sir Arthur Cotton." The result of these inquiries was that Government adhered to the remodelling project, proposed previously to Sir Arthur Cotton's report, with a few alterations in detail.

In 1868 the attention of the Government of India was again drawn to the question by a note submitted by Colonel Strachey, then Inspector-General of Irrigation Works, in which he pointed out that though the existing Ganges canal was able to supply the upper portion of the Doab, there were large tracts lower down which could never be brought under its influence, and that a better distribution of the available water in the river could be made by dividing it into tolerably equal proportions and constructing a lower canal, as originally suggested by Sir A. Cotton, to carry the water to the lower half of the Doab.

This led to the projection of the system of works now known as the "Lower Ganges canal," and to material alterations in the measures for rectifying and completing the old "Ganges canal."

The revised project for the latter contemplated an average discharge at the head of 6,000 cubic feet per second in the summer season, and 3,650 cubic feet in the winter; of these quantities 500 cubic feet were to be passed on to the new Lower Ganges canal, in each season, leaving 5,500 and 3,150 cubic feet per second to be utilized from the channels of the old canal in the summer and winter seasons respectively. The project of 1864 provided for the utilization, as in Colonel Cautley's original scheme, of an average full supply throughout the year of 6,750 cubic feet per second.

The revised project divides itself into two main heads:—

I. Works of extension required for the full utilization of the surplus volume of water made available for the upper portion of the Doab by the construction of the Lower Ganges canal. These were—

1st. The Deobund branch, 46 miles.
2nd. Extension of the Anoospshuhur (old Futtehgurh) branch, 43 miles.
3rd. Extension of the Bulundshuhur branch, 67 miles.
4th. Completion of distributary system.
5th. Drainage.

II. Alterations of existing main channel and the Cawnpoor branch to the junction with the Lower Ganges canal, to adapt them to the altered conditions of irrigation and navigation entailed by the opening of the lower canal.

The estimate for the canals as thus finally determined upon amounted to three million one hundred and eighty-three thousand three hundred and ninety pounds, but this sum did not include indirect charges.

The head of the Ganges canal is situated near Hurdwar, about 20 miles above the town of Roorkee. The main stream of the Ganges has at this point a discharge in the dry season of about 8,000 cubic feet per second. A little above the town of Hurdwar the Ganges throws off a small branch about 300 feet broad, which rejoins the river again about a mile and a half below Hurdwar. This branch has been utilized as the offtake of the canal, it has been deepened and the slope of the bed made uniformly 8½ feet per mile down to the Myapore regulating bridge and dam by which the supply of the canal is regulated. There are no permanent masonry works of any kind at the point where the branch leaves the main river, but the discharge is forced into the branch by temporary bunds which are made afresh every year.

At Myapore the headworks consist of a dam across the branch and a regulating bridge across the head of the canal. Both the dam and the regulating bridge are fitted with sluices, so that the discharge which is forced down from the Ganges can be entirely admitted to the canal, or can be entirely allowed to escape again to the Ganges, or any portion of it that may be required can be admitted. From the Myapore head-sluice to Roorkee the canal passes through the Khadir of the Ganges, from that point it follows the high land of the Doab. During its course through the khadir the canal flows nearly parallel with the foot of the hills and crosses all the streams, torrents, and drainages which flow from them. In the sixth mile the Ramipore torrent, which has a catchment basin of about 45 square miles, is carried across the canal by a masonry work termed a super-passage. This work is, in fact, an aqueduct carrying the torrent across the canal. The waterway provided for the torrent is 196 feet broad and 14 feet deep. In the tenth mile the Puttri torrent, which has a catchment basin of 80 square miles, is carried across the canal by a masonry work of similar design to the Ramipore super-passage, but the width of the waterway is 296 feet instead of 196. These torrents are subject to sudden floods of great violence.

In the thirteenth mile the canal encounters the Rutmoo torrent; this torrent has a catchment basin of about 126 square miles, it is about 21 miles in length, and the slope of its bed is about 8 feet per mile. This torrent is boldly admitted into the canal itself * over a

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* "Report on the Ganges Canal Works," by Sir Proby Cautley part iii. vol. ii.

masonry inlet; this inlet consists of a masonry platform provided with sluices which at all periods, except when floods are running, are closed by gates. The torrent passes out of the canal over a masonry dam immediately opposite to the inlet. This dam consists of forty-seven sluices of 10 feet in width, with their sills flush with the canal-bed; they are separated by piers 3½ feet thick. These are flanked on each side by five sluices of the same width, but having their sills raised to a height of 6 feet, with intermediate piers of the same dimensions as those in the centre sluices. On the extreme flanks are platforms raised to a height of 10 feet above the canal-bed, and corresponding in height with the rest of the piers. The amount of waterway, therefore, through the sluices, up to a height of 6 feet, is equal to 470 feet in width; to a height from 6 to 10 feet, it is increased to 570 feet; and when flood-water rises above that height, the water passes over the full extent of the masonry, which is 800 feet in width.

A regulating bridge is built across the canal immediately below this inlet and escape, so that the supply of the canal itself below the influx of the torrent may be independent of the amount of water which the torrent may throw into the canal. This regulating bridge is precisely the same as the regulator at Myapoor; it is fitted with sluice-gates, so that the discharge of the canal can be accurately regulated by it.

In the nineteenth mile, just before the canal leaves the khadir of the Ganges, it crosses the Solani river by an aqueduct. The Solani drains an area of about 216 square miles; it has a discharge in the highest floods of about 35,000 cubic feet per second, the fall of its bed being, in the neighbourhood of the canal, about 5 feet per mile. The aqueduct which carries the canal across this river has a total length of 15,700 feet. The banks of the canal on the up-stream side of the aqueduct are revetted by masonry steps for a distance of 10,713 feet, and for 2,723 feet on the down-stream side. The bed of the canal is raised considerably above the level of the country in the valley of the Solani river for a distance of about 1¾ miles above the aqueduct, and for about ½ mile below it; the greatest height of the canal-bed above the country at any point is about 24 feet. In the construction of this great embankment many methods of work were used. The last method was that of tilt-waggons drawn by a locomotive; this was supposed to be the first locomotive ever used in India; it was started on the 21st of December 1851. The aqueduct itself consists of fifteen arches of 50 feet span each through which the Solani flows; the extreme width of the foundations of the aqueduct is 252 feet. The waterway of the aqueduct itself is 172 feet broad; it is divided by a continuous wall along the centre, and piers fitted with grooves are built at each end, so that by planking up the grooves one-half of the aqueduct can be closed if necessary.

In addition to the two works where torrents are carried across the canal in super-passages, the work by which the Rutmoo torrent flows actually through the canal itself, and the great aqueduct which carries the canal over the Solani, there are in the first 20 miles of the Ganges canal no less than five masonry works which admit smaller drainages into the canal; the waterway of two of these minor works is 50 feet broad, there is one of 30 feet, one of 100, and one of 150.

After it reaches the high land of Roorkee, the main canal follows the high land between the West Kalli nuddi and the Ganges, the canal flows to the east of Mozuffurgur and to the west of Meerut; after passing Meerut the canal takes a rather circuitous course, following the high land nearly up to Bolundshuhur, it then runs for some distance almost parallel to the East Kalli nuddi for a short distance below Allygurh; here the main canal terminates, or rather, it bifurcates into the Cawnpoor and Etawah branches.

The Cawnpoor branch flows on the high land between the rivers Esun and Rind, and flows into the Ganges at Cawnpoor; it is 170 miles in length and navigable throughout. At the point of the bifurcation of the main line a masonry regulator controls the discharge down this and the Etawah branch.

The Etawah branch follows the high land between the Seyngoor and Rind rivers, and after a course of 170 miles flows into the Jumna near Humeerpore.

The Futtehghur or Anoopshuhur branch leaves the main line at the fiftieth mile of its course; it flows parallel to the Ganges at a distance of about 8 miles from the river, past Shahjahanpore to Anoopshuhur, at which point it formerly terminated, falling into the Ganges, after a course of 82½ miles, a little below the town.

The Bolundshuhur branch leaves the main canal at its one hundred and tenth mile; it flows between the Kurwun and Puttia nuddis. In the scheme of 1864 it was intended to be 45 miles long, but only 11 miles of it were opened in 1876.

The Kole branch leaves the main canal in the one hundred and fifty-second mile; it forms a cross line of communication to Anoopshuhur.

The nature of the country offers abundant facilities for the construction of escapes from the canals. These are necessary on account of the great length of the canals and the large body of water they carry. In addition to the works of the Rutmoo torrent, which can always be used for the escape of water, there are five escapes on the main canal, in the sixty-second, sixty-ninth, eighty-seventh, one hundred and forty-first, and one hundred and sixty-sixth miles. On the Cawnpoor canal there are four escapes, and there are three on the Etawah line in addition to others on the minor branches.

Up to the end of 1877–78 the actual expenditure on the canal had been three million and fifty-five thousand and fifteen pounds. The area irrigable is 1,205,000 acres.

Agra Canal.

This canal was formally opened in March
Irrigation commenced from it in the f